EXECUTIVE FUNCTIONING PROCESSES IN SIMPLE AND COMPLEX THEORY OF MIND TASKS

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Using a multimethod-multimodal approach, this study compared the contributions of executive function (EF) abilities (Go No-Go, Visual Search, 2-Back task, and Task Switching) to narrative comprehension tasks (False Belief, Strange Stories, Self-Reported Theory of Mind Inventory [TOMI-SR]) and a narrative production task (interpersonal decentering) in a sample of young adults. Separate regression models were conducted for each theory of mind (ToM) measure with EF measures as predictor variables and empirically selected demographic variables controlled. As expected, in this college student sample (N = 110), False Belief demonstrated a ceiling effect and was not associated with any EF ability. Task Switching and 2-Back accounted for significant variance in Strange Stories. No EF task significantly predicted performance on TOMI-SR or interpersonal decentering. Both story comprehension tasks (False Belief and Strange Stories) were significantly associated, but these tasks were not correlated with either self-reported ToM or interpersonal decentering. Several unanticipated demographic associations were found; having more siblings and English proficiency accounted for significant variability in Strange Stories; education, presence or absence of self-disclosed autism diagnosis and mental health diagnosis explained a large portion of variance in TOMI-SR; interpersonal decentering maturity differed significantly between cisgender men and cisgender women. Lastly, interpersonal decentering number of interactions demonstrated an advantage for individuals without diagnosed or suspected autism diagnosis. This study raises critical concerns regarding measurement method error variance and variability of task demands in explaining cognitive mechanisms relevant to social cognitive processes.

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CHAPTER 1

INTRODUCTION

An individual's ability to take another individual's perspective is a central aspect of virtually all our social exchanges. Humans act purposefully, and intentions drive their behaviors. Their actions contribute to bringing about change in another agent of social interaction. Our social interactions rely on bidirectional exchanges to engage with others, be it communication, cooperation, competition, or mutual participation in any interaction. These social behaviors depend on our ability to observe and understand how the other individuals in a social interaction feel, perceive, relate, and plan their views and behaviors, and to use this information to decide on and reflect on our own actions towards them.

Moreover, we construct and modify our understanding of beliefs and desires that might have governed the other individual's reasoning (For example, my friend sent me chocolates on my birthday because she thought I like chocolates). This abstract construct by which we conceptualize, relate, and explain others' subjective thoughts and reasoning is generally referred to as the theory of mind (ToM; Rakoczy, 2017). Understanding and identifying the underlying mechanisms of social cognitions has substantial implications in clinical neuropsychology, given its significance in several neurological and psychiatric conditions (e.g., McDonald, 2013) for targeting treatment modalities toward fundamental cognitive skills that support ToM abilities.

Recently, attention has been directed towards the mature aspects of ToM in adults (Apperly, Samson, & Humphreys, 2005). Perspective-taking ability is paramount for mature social cognitive development. An individual is expected to maintain a cordial relationship with co-workers and maintain harmony in their peer and romantic interactions. The capacity to understand another individual's perspective when they have differing opinions requires ToM to decenter from one's own beliefs, infer another individual's mental state, and comprehend their views, opinions, and beliefs. Understanding the theoretical underpinnings, cognitive and neural foundations of the reasoning processes, and domains on which the mechanisms of the ToM rely has been a recent focus of cognitive neuropsychology and cognitive neuroscience. Although ToM theories have been formed from extensive work with children, they remain germane for understanding social cognitive developmental behaviors among typically developed healthy adults. The existing developmental literature can likely inform the prevailing theories of social understanding among adults, and the conclusions drawn from adult research can extend the existing ToM developmental framework.

Much less attention has been given to the story-based methods for exploring the metacognitive processes of the theory of mind. The proposed study is designed to fill the gap in the current literature regarding the utility of using narratives for assessing mature perspective-taking processes in neurotypical young adults.

The following sections provide an overview of the existing efforts to conceptualize ToM, supporting cognitive processes of executive functioning mechanisms along with their neural correlates, the theoretical debate about the development of ToM and relevant assessment methodologies. The noteworthy steps pertinent to this project include researching the tasks most widely used to measure ToM abilities, less commonly used narrative assessment methods, and their association with executive abilities. Our study is designed to inform the existing literature regarding the use of narrative techniques in explaining ToM as a dynamic social information-processing ability using a mixed-method research approach.

Theory of Mind: A Construct of Social Cognition

Social cognition is an umbrella term that involves information processing abilities such as attention, perception, memory, and the like that are significant in a social context to provide a process-oriented explanation of social experiences (Frith, 2008). Initially, Brothers (1990) defined social cognition as "the processing of any information that culminates in the accurate perception of other individuals' dispositions and intentions." Adolphs (2009), taking a step further, popularly defined social cognitions as consisting of "psychological processes that allow us to make inferences about what is going on inside other people—their intentions, feelings, and thoughts." ToM is the social cognitive ability that facilitates understanding intentions, thoughts, and emotions of the self and others (Hughes & Leekam, 2004). In this regard, ToM is a cognitive rather than an affective construct (Baron-Cohen, 1988). Its development unfolds over time across various developmental stages (Brüne & Brüne-Cohrs, 2006). These abilities continue to mature as more complex capabilities throughout developing years beyond the childhood and adolescent years (Wellman, Cross, & Watson, 2001).

Conditions in which social cognitive mechanisms or perspective-taking abilities are not fully developed or are disrupted support the idea of the differential deficits in perspective-taking abilities regarding self, others, or both. The Diagnostic and Statistical Manual for Mental Disorders (DSM-5; American Psychiatric Association, 2013) recognizes the importance of social cognitive function, which is emphasized as one of the core neurocognitive domains (Henry et al., 2016). The deficits and difficulties in understanding the perspective of others have been associated with several neurodevelopmental and psychiatric conditions such as autism, attention deficit/hyperactive disorder (ADHD), and schizophrenia (Bora et al., 2005; Gottlieb, 2005; Kerr et. al, 2003), along with varied neuropsychological and psychological difficulties (for a review see Henry et al., 2016).

Studies have focused extensively on exploring autism spectrum disorder (ASD) for its core diagnostic criteria being deficits in social cognitive abilities (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001; Hillier & Allinson, 2002; Lombardo et al., 2010) as ToM gained popularity for its importance in autism studies (Baron-Cohen, Leslie, & Frith, 1985; Baron-Cohen, 2000). Children diagnosed with ASD display egocentricity on ToM tasks compared to typically developing children (Ahmed & Miller, 2011). However, there have been mixed findings in popular literature. Some suggest that individuals diagnosed with ASD show deficits on ToM tasks in attributing other's mental states (e.g., Hutchins, Prelock, & Bonazinga, 2012; Wimmer & Perner, 1983), their own mental states (e.g., Williams & Happé, 2010), or mental states in self and others combined (e.g., Brent et al., 2004; Carlson, Moses, & Breton, 2002; Perner, Frith, Leslie, & Leekham, 1989). However, most generally, studies have focused on their difficulties in comprehending others' mental states, which support their difficulty with differentiation between self and others in mentalizing processes (Baron-Cohen, Tager-Flusberg, & Cohen, 2000; Tager-Flusberg, 2007). Individuals with autism spectrum disorders show impaired cognitive and intact affective empathy (Jones, Happé, Gilbert, Burnett, & Viding, 2010), while high functioning autistic individuals show intact cognitive but impaired affective empathy. Similarly, individuals with psychopathic tendencies show preserved cognitive but an impaired affective component of social cognition (Blair, 2005; Jones et al., 2010; Shamay-Tsoory, Harari, Aharon-Peretz, & Levkovitz, 2010).

The association between social cognition and neurological conditions is predominantly drawn from brain impairment research findings that support the distinction between affective and cognitive components of social information processes (Shamay-Tsoory & Aharon-Peretz, 2007; Shamay-Tsoory, Tibi-Elhanany, & Aharon-Peretz, 2006). Schizophrenia, for instance, is a clinically heterogeneous disorder with several social interaction and related abnormalities.

Limitations in social interaction may not be a critical diagnostic component of schizophrenia (Burns & Patrick, 2007), but it is one of the significant predictors of prognosis.

There are several theoretical ambiguities and methodological inconsistencies in ToM research. Numerous cognitive models have been proposed to explain the complex nature of ToM with opposing arguments and theoretical discrepancies in the ToM literature. These contradictions are partly due to diversity of methodologies and measurement methods in the ToM literature, which have contributed to inconsistent results (Corbera, Wexler, Ikezawa, & Bell, 2013; Mehta et al., 2013).

First, the heterogeneity in the tasks utilized, operationalization of ToM, characteristics of the sample used, and the use of several different constructs to measure and investigate ToM cautions the comparability of the study design and methods. Second, perhaps a likely and crucial reason for this heterogeneity is a lack of a clear and comprehensive model encompassing all the dimensions of ToM. Third, the tasks that have been utilized in ToM studies lack psychometric soundness and validity when used in the clinical and general populations, reminiscent of Enright and Lapsley's (1980) conclusions in their comprehensive review of the role taking literature.

Mentalizing abilities are complex, yet most tasks focus on age and overlook validity of measures in the context of population variables (metacognitive abilities, cultural competence, cognitive maturity, presence of developmental disability, etc.). Finally, some studies have inconsistently utilized the factor structure method to comprehensively define the number of social cognitive dimensions and their relationships. For example, Adolphs (2009) and Frith and Frith (2008) used exploratory factor analysis to arrive at their bifactor model of implicit and explicit social cognitive processes while Browne et al. (2016) used confirmatory factor analysis, assuming that ToM and emotional perception load each on a unidimensional construct.

As noted, the discrepancies in the conceptualization, methods, diversity in assessment measures, the use of statistical procedures in arriving at the results, and the criteria they set to interpret their findings render these studies non-comparable. Given these limitations, the following review of dimensional models provides a comprehensive overview of some of the constructs and conceptualization of ToM. These factor structure models outline the scope, the number of social cognitive processes, and the relationship and interactions between social cognitive processes.

Dimensional Models of Social Cognitive Processes

The dimensional model approach of ToM has been explored using the factor structure method. Etchepare and Prouteau (2018) conducted a systematic meta-analysis to identify distinctive dimensions of social cognition from a neuropsychological perspective given its relevance in a wide variety of neurological, psychiatric, and geriatric conditions. They identified 11 studies between 1982 and 2017 that studied different facets of social cognition in the general and clinical populations that included various dimensions of social information processing.

Significant support for two factor-based ToM models was identified through the empirical exploratory and confirmatory factor structure of social cognition across these studies. The first model specified the levels of social information processing, while the other highlighted the nature of the information being processed (Etchepare & Prouteau, 2018). There has been substantial support for the dual-process social cognitive models of affective vs. cognitive social cognitive abilities, low vs. high social cognitive abilities, and implicit vs. explicit cognitive processes (Apperly & Butterfill, 2009; Frith & Frith, 2008; Keysers & Gazzola, 2007; Schaafsma et al., 2015). These models have received significant empirical support from clinical, developmental, and neuroimaging studies. Clinical research, neuroimaging, and lesion studies corroborate these models' utility in explaining social cognitive processes.

Affective and Cognitive Processes

Some studies have conceptualized and differentiated between affective and cognitive components of social information processing (e.g., Bell et al., 2009; Mehta, et al., 2014; Ziv, Leiser, & Levine, 2011), using these two factors to explain 56.5% to 75.7% of the variance in social cognitive abilities (Etchepare & Prouteau, 2018). Tasks that measure emotional processes such as facial emotion recognition, prosodic emotion recognition, alexithymia, and emotional awareness are grouped under the affective factor of social cognition. In contrast, tasks requiring participants to infer mental states, beliefs, and the ability to attribute intentions without relying on emotional abilities are labeled as cognitive factors.

For example, Ziv et al. (2011) assessed 75 neurotypical participants using social cognitive tasks. They used the first and second-order theory of mind tasks and a measure of matrix reasoning to compose their "cognitive theory of mind" factor. For their second factor, "emotion recognition and processing," they used tasks that assessed emotional processing and irony. Similarly, Etchepare et al. (2014) assessed healthy participants to draw a four-factor structural model. Factor 1 was composed of tasks that assessed facial emotion recognition, alexithymia, theory of mind and emotional awareness that they labeled as "emotional information processing." Factor 2, "cognitive theory of mind," consisted of only one intentions attribution task. Factor 3 was labeled as "emotional lexicon" using an emotional word fluency task. Lastly, factor 4, "facial emotional recognition" was comprised of one facial emotional recognition task. Collectively, they attributed factor 1, 3, and 4 to the affective component, and factor 2 to the cognitive component of ToM.

It is worth noting that Ziv et al. (2011) used the first-order and second-order ToM tasks to explain cognitive factors in their model. In contrast, Etchepare et al. (2014) had ToM as one of the tasks that loaded on their emotional information processing factor.

Low-Level and High-Level Processes

Mancuso, Horan, Kern, and Green (2011) suggested that the low-level and high-level functional distinction is noteworthy for functional outcomes that include social and work functioning relevant in psychosis. Apperly and Butterfill (2009) specified that high-level social information processes are taxing, and require substantial cognitive resources, particularly language and executive functions (EF). Moreover, high-level processes follow a developmental course and are partially, but substantially sustained by low-level processes. Etchepare and Prouteau (2018) reported that the low-level versus high-level factor structure explains 52% to 74% of the variance in social cognition in four studies.

Mancuso et al. (2011), in their study, analyzed the data collected from a sample of 85 individuals on the schizophrenia spectrum. Among the three identified factors, two factors were conceptualized based on the information processing complexity. Tasks that measured facial emotion recognition, non-verbal cue detection, and lie detection were labeled “lower-level social cues,” while tasks measuring the emotional management abilities and sarcasm detection were denoted as “higher-level inferential and regulatory processes.” Another study (Thaler, Allen, Sutton, Vertinski, & Ringdahl, 2013) utilized several social cognition tasks to assess a psychiatric sample (diagnosed with bipolar disorder or schizophrenia). Their first identified factor, “social/emotional processing,” consisted of basic facial and social stimuli. In contrast, factor 2, “Theory of Mind,” used tasks that measured inference and mentalization of others’ implicit intentions.

Similarly, Bliksted, Fagerlund, Weed, Frith, and Videbech (2014), in their analysis of patients with schizophrenia, interpreted social cognition based on their information processing complexity. They utilized tasks that assessed simple belief systems (low-level functions dimension) and accuracy and understanding of ToM states (high-level functions) and the tasks that assessed the capability to detect sarcasm and sincerity. A third factor in their analysis consisted of tasks that differentiated between sarcasm and sincerity. Buck, Healey, Gagen, Roberts, and Penn (2016) assessed social cognitive structure in their comparative study between 50 controls and 65 patients with schizophrenia. They named factor 1, "hostile attributional style", while Factor 2 was named "higher level inferential and regulatory processes" which was comprised of tasks that measured ToM and jumping to conclusion tasks. Among their three extracted factors in healthy adults, factor 3 was "lower-level social cue detection" that used tasks such as the perception of emotion. These studies highlight that facial emotional detection tasks capture low-level processes, whereas tasks that assess sarcasm and identification of intentions are categorized as taxing, explicit high-level measures.

Implicit and Explicit Processes

A two-systems framework using explicit and implicit abilities for explaining ToM processes has been proposed recently (Apperly & Butterfill, 2009; Frith & Frith, 2008; Keysers & Gazzola, 2007; Schaafsma et al., 2015). According to the two-systems framework, an individual's ability to infer mental representations of others is comprised of several perceptual and cognitive abilities and associated processes (Mitchell, et al., 2005; Schaafsma et al., 2015) such as attributing and inferring feelings, intentions, and understanding from observable cues conveyed via human action, motion, and facial expression (Schaafsma, 2015). The automatic implicit abilities involve visually perceiving relevant social information conveyed via body motions, facial expressions, voice, and other easy-to-perceive cues. On the other hand, explicit cognitive abilities comprise context-relevant use of language, higher-order reasoning, working memory, inhibition, and other executive functioning higher-order reasoning abilities.

In the context of understanding mental representations, implicit social perceptual processes are automatic, quick, and efficient at picking cues. These cues require decoding using implicit processes that are automatic, reflex-like. For example, gaze measures are usually used to assess implicit processes of ToM reasoning (e.g., Clements & Perner, 1994; Southgate et al., 2007). Explicit reflective cognitive processes are slower and more taxing since they require an evaluation and reevaluation of context-dependent belief systems (Apperly & Butterfill, 2009; Frith & Frith, 2008; Keysers and Gazzola, 2007). Explicit processes are context-dependent and culturally shaped, making them more conscious, cognitively demanding, and slow for the observer.

Developmental literature offers strong support for the hierarchical development of a dual system approach for conceptualizing social information processes. Onishi and Baillargeon (2005) provided support for 15-month-old children's implicit ability to recognize that someone's belief or representation about a situation may differ from reality (false belief). In their experiment, infants watched an actor hiding a toy and leaving the situation, after which the toy was moved to a different location. By noting infants' gaze time during the true belief vs. the false belief situation, the authors established that children can adequately discern others' mental states.

However, children may not demonstrate explicit abilities until the age of four years, given these abilities' substantial reliance on language and EF capacities. Subsequent to the development of perceptual processes, children acquire the ability to recognize intentions and desires (Bartsch & Wellman, 1989), followed by, after middle childhood, the ability to identify lies, ironic remarks and sarcasm (Demorest, Meyer, Phelps, Gardner, & Winner, 1984). Taken together, social perceptual (implicit) and metacognitive processes (explicit) collectively represent socially relevant information and facilitate significantly predicting individual differences in understanding mental and emotional representations in social encounters with the help of observable cues and spoken language. Implicit processes such as detection of motion, visual cues, and facial expressions are required to perform false belief tasks adequately. The reactivity towards social cues is crucial in establishing attention and engagement and laying the foundation on which more explicit executive processes build.

Dimensional Conceptualization of ToM

ToM literature has provided ample support for the several dichotomous processes. As mentioned above, Adolphs (2009) and Frith and Frith (2008) described low-level social cognitive processes as implicit, unconscious, and quick, and high-level processes as explicit abilities that are slower, conscious, and require cognitive effort. A dual-modality view is in line with the classic dual process system (see Happé, Cook, & Bird, 2017) of reflexive and reflective processes (Lieberman, 2007), implicit and explicit processes (Frith & Frith, 2008), or controlled and automatic processes (Schneider & Shiffrin, 1977).

Conversely, although several studies have proposed two-dimensional models of low-level versus high-level, and affective versus cognitive information processing, it is worth reporting that some researchers did not arrive at similar conclusions exploring these models. For instance, several researchers (e.g., Browne et al., 2016; Corbera et al., 2013; Stouten et al., 2015) indicated no difference between cognitive and emotional information processing and both cognitive and emotional processes loaded on a single factor. Moreover, similar conclusions regarding the factor structure model in neurotypical adults cannot be drawn. For example, Mehta et al.'s (2014) two-factor model included affective and cognitive dimensions, whereas a third, externalizing bias, factor distinctively loaded in the schizophrenia group.

Figure 1

A Two-Dimensional Model of Social Cognition

Note. A two-dimensional model of social cognition is shown (adopted from Etchepare & Prouteau, 2018).

Social cognitive processes rely on several higher cognitive abilities to construct representations of the self in relation to others and vice versa to flexibly guide social behaviors. Some researchers have attempted to bridge the gap between low- and high-level processes with affective and cognitive processes by merging these models into a two-dimensional model of social cognition. Etchepare and Prouteau's (2018) meta-analysis review offered an integrated circumplex model by creating a two-dimensional social cognition model with low and high information processing intersecting affective and cognitive processing dimensions (see Figure 1). The authors recommended combining low-level and high-level with affective and cognitive components of social cognitions to further the field of ToM and clinical practice, and benefit from crossing perspectives to integrate the models of social cognitions.

Some researchers, for instance, Mehta et al. (2014) initially provided a two-factor solution indicating social-emotional processes and social inferential (cognitive) processes in their study with neurotypical participants. Following their analysis, they concluded that although they explained social and emotional processes, the component of social inferential processing further consists of low level (understanding the goals of action) and high-level mechanisms (understanding complex judgment of others) of social cognitive abilities. Moreover, Thaler et al. (2013) identified that social/emotional processing and theory of mind factors of social cognition were comparable to Mancuso et al.'s (2011) low- and high-level distinction and Ziv et al.'s (2011) affective and cognitive factor distinction. Other studies that have identified emotional perception (processes) and the cognitive ToM abilities (Bell et al., 2009; Browne et al., 2016; Etchepare et al., 2014) can also be interpreted as a variant of low- and high-level processes. These studies emphasized the significance of a robust conceptualization of the social cognitive abilities to provide a global model of social cognition.

Under this integrative social cognitive model, the tasks used to assess social cognition can be distinguished based on the nature of information processed. Emotional information and tasks assessing emotions can fall under affective processes. In contrast, tasks that assess intentions, beliefs, mental states, and desires in which emotions are either absent or secondary, can be grouped under cognitive processes in the circumplex model (see Figure 1). Likewise, tasks can be classified by the level of information processing; low-level processes that are implicit, automatic, and reflex-like and high-level information processes that are explicit, and conscious rely on complex cognitive processes such as EF abilities. The different processes of ToM (such as self/other, implicit/explicit or affective/cognitive) differently trigger neural pathways and mechanisms that represent distinct, yet interconnected processes required to perform varied ToM functions.

In addition to bidirectional conceptualization, it is doubtful whether cognitive mechanisms, undifferentiated brain regions, and environmental reciprocal interchange support ToM abilities, or there are predetermined specific functions and brain regions responsible for ToM output. The following sections will highlight these arguments and the domain specificity and domain generalizability of ToM, and explore how these abilities might be associated with cognitive processes. Association between neural regions related to mentalization and cognitive processes is also discussed.

Domain-Specific Versus Domain General Social Cognitive Processes

The ongoing debate between the domain-specific and domain-general contributions towards social cognitive processes has gained significant attention in the developmental literature. The former argument rests on the claim that there are specialized social cognitive processes and brain regions relevant for ToM abilities in neurotypical adults (Frith & Frith, 2003; Leslie & Thaiss, 1992). On the contrary, the latter argument suggests that several (domain-general) cognitive processes, such as inhibition, attention, and working memory, contribute to the execution of ToM skills (Astington & Jenkins, 1999; Carlson, Moses, & Claxton, 2004).

Saltzman and colleagues (2000), in their study with older participants, found that ToM had a positive correlation with verbal fluency, design fluency, and problem-solving. ToM and related constructs, among adults, resemble the way that crystallized intelligence is conceptualized. The authors stated that ToM abilities, once developed, remain stable and invulnerable to decline over time or cognitive aging (McKinnon & Moscovitch, 2007). In this manner, the conceptualization of ToM abilities can be regarded as modular in nature, since once developed, specific ToM abilities operate automatically without having to rely on domain-general processes.

Strong support has been provided for the domain specificity of the social cognitive abilities during the early developmental stages (Leslie & Thaiss, 1992). For ToM abilities, the evidence for a modular perspective was primarily adopted from research conducted on children with autism (Baron-Cohen, 1995; Happé, 1994; Ozonoff, Pennington, & Rogers, 1991) which indicated that children with autism demonstrate impaired ability to understand the perspective of others. In contrast to their impaired performance on the ToM tasks, such children exhibit relatively intact performance on tasks that do not require taking the perspective of another person (Charman & Baron-Cohen, 1992).

Likewise, several more recent clinical studies have supported the domain-specific nature of ToM abilities as a discrete area of cognitive functioning and its partial dependence on neurocognition (Addington & Piskulic, 2011; van Hooren et al., 2008; Ventura, Wood, & Hellemann, 2013). For instance, in a study conducted in a clinical population sample suffering from schizophrenia, 25% of the participants exhibited intact neurocognitive abilities but impaired social cognition (Fanning, Bell, & Fiszdon, 2012). In essence, social cognitive impairments remarkably impair social functions and adjustment in work settings in schizophrenia (Brekke, Kay, Lee, & Green, 2005) in the presence of intact cognitive abilities (Fanning et al., 2012). Moreover, meta-analytic studies identified a limited region within the medial prefrontal cortex (mPFC), the temporal poles and the temporoparietal junction (TPJ), that activated when participants performed the false-belief task in comparison to participants who performed on a false-photograph identification task (Sabbagh & Taylor, 2000; Saxe & Kanwisher, 2003; Saxe & Wexler, 2005). These studies provide evidence for the domain specificity for those ToM processes that are operated automatically, producing output that is required to be processed further by higher-order processes (Fodor, 1983; Moscovitch, 1992; Moscovitch & Umilta, 1990).

However, the modular view of ToM has been challenged by several studies based on evidence of the association between ToM and EF abilities among typically developing children and children with autism (e.g., Carlson, Moses, & Brenton, 2002; Sabbagh, Xu, Carlson, Moses, & Lee, 2006; Zelazo, Jacques, Burack, & Frye, 2002). Apperly, Samson, and Humphreys (2005) argued that there is no reliable evidence for the presence of domain-specific constructs to explain ToM since the belief reasoning task explicitly designed to measure ToM does not differentiate between specific and general domains.

Apperly, Back, Samson, and France (2008), in their experiments, required participants to read sentences that described the color of an object and a man's false-belief ("the man thinks the object on the table is red") about its color. The reality stated in the false belief condition was contradictory to the belief ("Really, the object on the table is blue."). In the unrelated condition, the reality was not in conflict with the belief ("Really, the object on the chair is blue"). Participants then saw the pictures that presented either the reality or the man's belief regarding the object's color to judge if the image represented man's reality or his false belief. The investigators found that the participants judged quicker and more accurately in the unrelated scenario than in the false-belief scenario. They concluded that false beliefs were harder to hold in mind, which consequently slowed their judgment regarding belief and reality. Thus, these findings highlight that perspective-taking is not instantaneous as would be expected if ToM was modular in nature. They emphasized the role of executive control (see below) in the expression of belief reasoning tasks popularly used to measure ToM abilities.

Apperly et al.'s (2008) study exemplifies research participants' perspective about an individual's true and false beliefs about an object. The following section provides an overview of the relevant studies exploring behavioral, cognitive, and neuronal correlates associated with self and others' perspectives and theoretical underpinnings of such mental state representations.

Self and Other Perspective Distinction

Relevant to the domain-general contributions of EF abilities in explaining ToM maturity is the distinction between mental state attributions associated with self-oriented and other-oriented beliefs. It has been proposed that the ability to reflect on others' mental states involves separate underlying mechanisms than when one is reflecting on their own mental states (e.g., Decety & Sommerville, 2003; Hartwright, Apperly, & Hansen, 2012; Jardri et al., 2011; Jeannerod & Anquetil, 2008). Some studies have explored the magnitude of the response time distinction between self and other's perspectives, with results highlighting that the presence of another individual likely influences participant's behaviors (e.g., Kovács, Téglás, & Endress, 2010; Samson, Apperly, Braithwaite, Andrews, & Bodley Scott, 2010).

Samson et al. (2010) asked participants to judge their own or another person's same or differing perspectives in a series of visual perspective-taking experiments. The investigators observed that participants struggled to ignore someone else's perspective when making self-perspective judgments even when specifically asked to take self-perspective or when provided the opportunity to ignore the other person's irrelevant perspective strategically. Apperly, Riggs, Simpson, Samson, and Chiavarino (2006) investigated the automaticity of belief reasoning on false belief tasks. The researchers identified that adult subjects performed more deliberately and slowly when unexpectedly asked about another person's belief about the location of an object than about the actual location, contrary to Samson et al. 's (2010) findings, suggesting that perspective-taking is deliberate rather than spontaneous. Back and Apperly (2010) further supported this assumption and indicated that inferring others' beliefs requires conscious effort to understand their perspective and beliefs.

There are some conflicting findings regarding how self-oriented and other-oriented information is processed. Kovács et al. (2010), using a visual object detection task, claimed that others' perspectives and beliefs are processed automatically similar to the self-perspective regardless of the nature of the task, with no significant difference in response latency. On the contrary, Back and Apperly (2010) utilized sequences of images in which the location of the object and character's belief about the object location frequently changed. These authors argued that when the task explicitly requires participants to take the perspective of others, they take longer than in the self-perspective condition, and their reaction times vary from visual detection to identifying participants' belief regarding the change of location.

To elaborate on the concept of self and other perspectives, Qureshi, Apperly, and Samson (2010) explained the difference between awareness of distinct knowledge states and consciously taking someone else's perspective. According to them, the awareness of someone else's mental state being different is not equivalent to the explicit knowledge about the nature of their mental state, and consciously adopting someone else's perspective. However, self and other perspectives cannot be discerned from tasks since distinctive measures are used to study self-versus-other conditions, making study design and conclusions difficult to compare (Apperly et al., 2006; Bradford et al., 2015; Samson et al., 2010).

Bradford et al. (2015) attempted to resolve this problem by designing a false-belief task with matched belief states from the self-perspective and other perspectives, keeping the same sentence structure to compare self and other perspectives equitably. The authors explored self-oriented and other-oriented ToM abilities using the behavioral measures of reaction time and error rate, and their differential association with EF abilities (gender and emotion congruent and incongruent Stroop Test; Ekman & Friensen, 1976) among the typically developed adult population. They recruited 62 adult participants between the ages of 18 and 55 (50 females; mean age 22.8 years). Their results revealed a measurable dissociation between self-perspective and other perspectives on a behavioral level, with significantly more errors and slower reaction times when participants were asked to recognize others' mental states than when they responded to self-oriented questions. Also, reaction times across false belief trials were much shorter when they shifted from others' perspectives to self-perspective than when the participants were asked to switch to others' perspectives. Bradford et al.'s (2015) analysis highlight that self-perspective is automatic and always processed first regardless of the situation.

Humans are inclined to process self-perspective regardless of the task-demand, while other-perspective is processed only when explicitly demanded by the situation. The results from several fMRI studies (e.g., Rothmayr et al., 2011; Van der Meer, Groenewold, Nolen, Pijnenborg, & Aleman, 2011) have also identified distinctive cognitive activation when tasks require perspective shift between self and other. However, the cognitive mechanism for self-oriented processing remains activated, but inhibited, even when an individual is required to take others' perspectives (Decety & Sommerville, 2003).

Understanding the mechanisms of ToM is crucial for examining the relationship between mentalizing processes and cognitive abilities to draw conclusions regarding domains specificity and domain generalizability of ToM. The following sections outline executive functioning and its specific domains that make advanced ToM a taxing and deliberate task, followed by describing empirical studies that have explored the relationship between EF abilities and ToM. Lastly, we summerize the contributions of EF abilities to explaining ToM task performance after highlighting their shared neural correlates in order to provide rationale for hypotheses.

Executive Functioning (EF)

Executive functions (EF) are described as the "complex set of processes" which facilitate our ability to adapt to novel situations (Strauss, Sherman, & Spreen, 2006). They are the cognitive control, "top-down mental processes" (Diamond, 2013), and are conceptualized to have the elements of (1) volition; (2) planning; (3) purposive action; and (4) effective performance (Lezak et al., 2004, p. 1162). EFs are cognitive processes that enable an individual to complete goal-driven tasks (Lezak et al., 2004). They support our cognitive control by selecting, attending, and monitoring behaviors to perform goal-directed actions. EF encompasses a constellation of cognitive abilities that regulate, manage and support other cognitive functions that include self-monitoring, planning, problem-solving, cognitive flexibility, working memory, inhibition and other relevant abilities (Anderson, 2002; Delis et al., 2001a; Miyake et al., 2000; Miyake & Friedman, 2012). Many models attempted to define EF domains, yet there is no agreement on a single definition of what constitutes EF components (for a comprehensive review, see Chan, Shum, Toulopoulou, & Chen, 2008).

According to Luria's (1966, 1973) model, the human brain consists of interactive functional units including brain stem, responsible for the regulation and maintenance of cortical arousal; temporal, parietal and occipital regions for encoding, processing and storage; and anterior brain regions such as frontal lobes, implemented for planning and regulating behavior. Norman and Shallice (1986) presented the supervisory attentional system (SAS) model. This model extended Luria's conceptualization of frontal lobe functioning and elaborated that there are two systems involved in EF abilities. The scheduling system oversees the routine and over-learned behaviors and prioritizes routine tasks (e.g., preparing water for coffee before frying eggs). On the other hand, the supervisory attentional system regulates non-routine tasks such as planning, decision-making, and troubleshooting. Stuss and Benson (1986) proposed a three-system tripartite model. According to them, the three systems are (1) an anterior reticular activating system (ARAS) for arousal and alertness, (2) the diffuse thalamic projection system for monitoring phasic changes from distraction, (3) and the fronto-thalamic gating system for complex processes such as planning, monitoring, response selection, and collectively tracking attentional and EF processes (Chan, Shum, Toulopoulou, & Chen, 2008, p. 205). However, all models unanimously agree that EF constitutes complex problem-solving abilities (Ahmed & Miller, 2011).

EF abilities are effortful and require a conscious attempt to demonstrate cognitive control to perform demanding tasks. Several researchers have concluded that there are three core EF abilities (e.g., Lehto et al., 2003, Miyake et al., 2000), namely inhibitory control, working memory, and cognitive flexibility. Higher-order cognition functions such as planning, problem-solving, and other similar skill sets are built on core EF abilities of inhibition, working memory, and cognitive flexibility (Collins & Koechlin, 2012; Lunt et al., 2012). EFs are essential skills required to perform successfully in school and work, social interactions, and cognitive and psychological development.

Several tasks and tests assess EF, though very few can effectively separate each ability (see below). A cognitive-process approach emphasizes the hierarchy of skills required to perform traditional EF tasks (Delis et al., 2001a; Homack et al., 2005). This approach facilitates our ability to plan, organize, focus, inhibit and multitask activities successfully (Wade, Prime, Jenkins, Yeates, Williams, & Lee, 2018) and provides conscious control of our thoughts and behaviors (Oh & Lewis, 2008).

Attention

Attention is the ability to selectively concentrate on one stimulus while ignoring the other equally potent stimuli by using focused cognitive resources (Anderson, 2004). Either attention is goal-directed and initiated consciously (top-down), or it is a stimulus-driven implicit (bottom-up) process (Dajani & Uddin, 2015). The top-down attentional processes are supported by the dorsal attentional network (DAN) consisting of the intraparietal sulcus (IPS) and frontal eye field. Bottom-up attentional processes are mediated by the ventral attentional network (VAN) that includes the right temporoparietal junction (TPJ) and ventrolateral prefrontal cortex (vLPFC; Corbetta & Shulman, 2002). Both networks work cohesively to support EFs successfully. For instance, in a laboratory experiment, unexpected cue change may direct attention to a distinct characteristic via the VAN. On the other hand, cues explicitly provided by the experimenter may excite a top-down attentional mechanism via DAN (Dajani & Uddin, 2015).

Several models of attention have been proposed. Cognitive processing models (for example, Mirsky et al., 1995) base their observations in healthy individuals and highlight four distinct components of attention using factor analysis that include the ability to focus, execute, sustain, encode and shift. The neuroanatomical model (Posner & Rothbart, 2007) explains attention as the function of vigilance, orienting to selective information, and executive control. Sohlberg and Mateer (2001), on the other hand, provided a clinical model of attention through their cognitive rehabilitation work with patients suffering from neurological pathologies. They divided attention into five different components in a hierarchical order that include:

1. Focused attention that is attending discretely to basic internal and external sensory stimuli,

2. Sustained attention to maintain a response continuously with vigilance to support mental control and working memory processes,

3. Selective attention requires maintaining cognitive set by selectively attending to a chosen stimulus while simultaneously ignoring other competing internal and external distractors,

4. Alternating attention by shifting between different cognitive tasks and maintaining "set" with cognitive flexibility, and

5. Divided attention to simultaneously respond to multiple tasks or task demands and provide behavioral responses by monitoring several stimuli.

Attention provides a backdrop for every EF ability (see Appendix Table B.1), and several cognitive domains (explained below) require a combination of the above-mentioned attentional processes (Strauss, Sherman, & Spreen, 2006).

Inhibition

The ability to control one's behavior, attention, thoughts, and emotions is the fundamental cognitive skill. Through inhibitory functions, an individual keeps the predispositions, such as biases, and schemas, and instantaneous inclinations, such as emotional and behavioral reactivity, in check. In the absence of inhibitory control, our behaviors would be repetitive, conditioned, instinctual, and impulsive (Diamond, 2013). Inhibitory control facilitates disengagement and attention to target stimuli and suppresses our attention to other objects and stimuli from interfering (see Appendix Table B.2). For example, selective attention is required to communicate at a cocktail party by inhibiting the interference from other visual and auditory stimuli, which often attracts our attention. These extraneous stimuli are exogenous, and our attention towards them is automatic, involuntary, bottom-up, and driven by the stimuli's intrinsic properties (Posner & DiGirolamo 1998; Theeuwes 1991).

Ignoring the unwanted stimuli and focusing on the target stimuli require conscious voluntary effort. This inhibitory function is also called attention control or attentional inhibition, which is a volitional, top-down, active, and a goal-driven process of executive control (Posner & DiGirolamo 1998; Theeuwes, 2010). Suppressing the prepotent mental states is called cognitive inhibition, which requires the resistance of extraneous thoughts other than required by the task demand (Anderson & Levy, 2009). Inhibition also constitutes suppression of the previously learned material from interfering with the new learning (proactive interference; Postle et al. 2004) and suppressing the new learning when accessing previously learned material (retroactive inhibition). Cognitive inhibition assists and fosters working memory processes (see below).

Self-control is another variant of inhibitory processes that demands controlling behaviors, feelings, emotions, and thought processes from reacting instantaneously. Inhibitory processes help people to resist temptations, premature actions, impulsive reactivity, and reflexive behaviors. The ability to sustain activity, not giving up and sustain self-control, is also associated with having fluid inhibitory controls (Louie & Glimcher, 2010). Self-control is a function of inhibitory control that is required when an individual is expected not to blurt out responses, react impulsively, or arrive at premature conclusions by inhibiting undesired behaviors.

The region of the subthalamic nucleus is implemented in inhibiting premature impulsive responses (Frank, 2006). In an analysis, Simpson and colleagues (2012) hypothesized and tested the assumption that being provided more time enables automatic thoughts, which are instantly triggered by stimulus, to reach a near response threshold, and fade away, allowing the situationally appropriate response to reach succession. Their analysis supported the assumption that inhibiting a prepotent response requires a cognitive effort that slows down the instantaneous desired response (Simpson & Riggs, 2007). Inhibition of action and inhibition of attention appear to be highly correlated and fall under a single factor in factor analyses (Friedman & Miyake, 2004).

Working Memory

Working memory is another core executive function that combines the short-term information storage system with mental manipulation of the information when the stimulus is not perceptually present (Baddeley & Hitch, 1994; Smith & Jonides, 1999). Working memory is frequently considered synonymous with short-term memory. Short-term memory holds information in mind for a brief period, whereas working memory is the manipulation of that information. They also load onto separate factors in factor analyses in children, adults, and adolescents (Alloway et al., 2004; Gathercole et al. 2004). Although working memory is a core component of EF abilities, some researchers define working memory more broadly, and on the same level as EF skills. For example, Kane and Engle (2000) explained working memory as an ability that keeps the information in a retrievable state and inhibits distractors to maintain attention at the task. Baddeley and Hitch (1994), in their working memory model, elaborated that working memory includes inhibitory control, enables cognitive flexibility, shifts attention, and provides multitasking skills. Miyake et al. (2000), using structural equation modeling, identified that inhibition, set shifting, and working memory positively correlate with EF constructs. However, most investigators maintain that working memory is the mental manipulation of information (e.g., Diamond, 2013; Smith & Jonides, 1999).

Furthermore, working memory and selective attention have been used synonymously since focusing on the information held in mind can be explained as maintaining attention momentarily. Selective attention and working memory also share the prefrontal, parietal system, a region implicated for selective attention and limiting interference from irrelevant stimuli (Awh

& Jonides, 2001; Gazzaley & Nobre, 2012; Ikkai & Curtis, 2011; Nobre & Stokes, 2011).

There are two types of working memory: verbal/auditory memory and non-verbal visuospatial working memory. Working memory ability is critical for relating information that happens over time, what happened earlier, and that can be related to something that comes later. Tasks such as mental math, mentally reorganizing, rearranging, reordering items and objects, updating new information in awareness, considering and weighing alternative options, and drawing general conclusions by comparing their merits are some of the everyday tasks that rely on working memory capacity. Working memory provides the cognitive framework to establish conceptual awareness rather than perceptual knowledge to facilitate decision making.

There are some disagreements whether inhibition is a separate component of EFs or inhibition is a component of the working memory process (Diamond, 2013). Some researchers have suggested that inhibition should not be considered a separate ability (Egner & Hirsch, 2005; Hanania & Smith, 2010; Nieuwenhuis & Yeung, 2005). Another opinion suggests that inhibitory control and working memory rely on a limited capacity system and are equally influenced when the demand on one ability influences the other (e.g., Engle & Kane, 2004; Wais & Gazzaley, 2011). Hasher and Zacks (1988) consider cognitive inhibition as a component of working memory since inhibitory processes are required to perform a working memory task.

Cognitively demanding tasks rely on the inhibitory controls and working memory for their successful completion (see Appendix Table B.3). Both these core abilities support and depend on each other (Diamond, 2013). Working memory supports inhibitory control by allowing individuals to hold the task demand in mind, allowing them to inhibit distracting exogenous and endogenous factors (for example, remembering to make a phone call before sitting down to watch TV). By holding relevant information in mind, we exercise control, inhibit a prepotent response, and minimize errors to guide our actions for arriving at the desired outcome.

Inhibitory control processes sustain working memory processes. To appropriately relate and weigh multiple ideas, factors, and conflicting arguments, an individual is required to inhibit premature focusing on one aspect of the information, and resist arriving at premature conclusions. For maintaining focus, one must inhibit internal and external distractions. Similarly, inhibitory functions aid working memory by limiting several ideas to come to foreground simultaneously, gating irrelevant information, discarding irrelevant information, and keeping our thoughts organized (Hasher & Zacks, 1988; Zacks & Hasher, 2006).

Duncan et al. (2008) developed a test to assess how mental cluttering influences working memory. To test this assumption, they instructed a group of participants on a letter and a number task. Participants were then told to ignore the numbers and focus on letters throughout the task. Another group of participants was instructed on the letter task. The stimuli were presented in two columns with the verbal instructions to "watch left" or "watch right" to read the letter. The instructions were then switched to visual cues and participants were required to attend to the right column if they see a plus sign (+ right) and attend the left column if they see a minus sign (- left). It was observed that participants started the trials on the correct side but continued to stay on the same side regardless of the instructions. Test cues (+/- signs) were either ignored, neglected, or confused throughout the performance. Interestingly, participants could follow the instructions, and they recalled the rules of the task in the beginning and after the task administration. The authors concluded that simultaneously holding facts, rules, and requirements of a task in mind creates cognitive load, which likely causes participants to lose important task components.

Although it is difficult to detangle inhibitory controls from the working memory task, the influence of either inhibitory controls or working memory demands can be minimized by suppressing the memory demands. For example, a Spatial Stroop task tells the participants where to responding by pointing the cursor on the screen to reduce memory influence. In this task, four arrows point at the four corners of the screen (upper left, upper right, lower left, lower right). Each arrow is presented individually, either congruent to screen location (e.g., upper left arrow displayed in the upper left corner) or incongruent condition (e.g., upper left arrow placed in the lower right corner. Participants are required to follow the pointing direction of the arrow to respond while ignoring the corresponding position by pressing keys. Conversely, reordering items and lists according to a predetermined rule (according to alphabets, number, size, proximity) relies less on response inhibition than on working memory.

Cognitive Flexibility

The third core domain of EF is cognitive flexibility. It is the ability "to appropriately adjust one's behavior," according to changing situational demands and environment (Dajani & Uddin, 2015). This ability builds on the other two core EF abilities of inhibition and working memory and matures much later in development (Davidson et al., 2006; Garon et al., 2008). There are several favorable outcomes associated with higher cognitive flexibility such as superior reading ability (Pascale et al., 2014), stress tolerance and resilience to adverse life events (Genet & Siemer, 2011), greater creativity (Chen et al., 2014), and better life quality among older adults (Davis, Marra, Najafzadeh, & Liu-Ambrose, 2010).

The complexity in defining cognitive flexibility comes from the intricacy of the construct and the multitude of perspectives used in defining this ability in the literature (see Appendix Table B.4). More often, cognitive flexibility is defined by the abilities involved in measuring this construct such as attentional flexibility (Vilgis, Silk, & Vance, 2015), attentional set-shifting (Owen et al., 1991), and task switching (Monsell, 2003). Dajani and Uddin (2015) defined the construct of cognitive flexibility in a behavioral paradigm and outlined its neural correlates. According to these authors, cognitive flexibility is the “emergent” ability of EF, measured using the tasks of set-shifting and task switching. The participants are required to switch back and forth between two tasks simultaneously, depending on the cue. For example, in one such task, participants are required to respond to different cues by categorizing the stimuli either by a vowel/consonant or odd/even (Badre & Wagner, 2006). Alternatively, a different task may require participants to switch attention and shift set (attention and set-shifting task) between different features and characteristics of the stimuli such as shape, color, form, number [e.g., Wisconsin Card Sorting Test (WCST); Berg, 1948; Grant & Berg, 1948; Heaton et al., 1993].

In the hierarchy of cognitive flexibility, set-shifting is considered a lower-level ability that requires less cognitive effort than task switching, a more complex cognitive phenomenon (Crone et al., 2006a). Nevertheless, both abilities suffer from “switch cost,” a decrease in response accuracy and response speed. Switch-cost occurs as a result of inhibition of previously learned response rules and the reconfiguration of a new response set and rule (Badre & Wagner, 2006; Monsell, 2003).

There are several aspects of cognitive flexibility, such as a change in spatial perspectives (how would this object be perceived if I look at it from a different direction), or interpersonal perspective (let me think about this situation from my partner’s perspective; Diamond, 2013). An important characteristic of cognitive flexibility is to continuously modify and update our thinking about a situation, and not be stuck on details, or unnecessary details. For example, if one way of thinking is no longer relevant, cognitive flexibility provides problem-solving perspectives and coming up with new ways of perceiving a situation. Cognitive flexibility does not necessarily mean stacking various EF abilities, but using information and manipulating all the available details in real time to flexibly adjust responses from one situation to another (Dajani & Uddin, 2015).

Several forms of EF abilities are executed coherently to perform a task that requires cognitive flexibility. From the initiation of attention to identification of the perceptual characteristics of a surrounding, situation, or a task, followed by recollection of previous knowledge about each stimulus, assimilation of current aspects of the stimulus, to inhibition of previously known facts if former information can hinder adjustment to the task at hand are all integrated to demonstrate cognitive flexibility. To exercise cognitive flexibility, we are required to inhibit our previous perspective and engage in the process of working memory to weigh different aspects of perceiving a situation carefully. In this regard, inhibitory control and working memory provide the foundation to successfully perform tasks requiring cognitive flexibility (Diamond, 2013).

EF and Brain Regions

As highlighted above, EF skills comprise a constellation of cognitive abilities, and several tasks are designed to assess these functions. Several brain regions play a significant part in the performance of EF abilities (see Appendix C). The EF ability of response inhibition is strongly implicated in activating anterior cingulate cortex (ACC), dlPFC, and superior parietal lobe (Aron, Robbins, & Poldrack, 2004; Wager et al., 2005). These very areas have shown activation during the performance of working memory tasks along with increased ACC and inferior frontal gyrus (IFG) activation in individuals with strong working memory capacity (Osaka et al., 2004). According to Veltman, Rombouts, and Dolan’s (2003) findings, working memory activates parietal areas along with ventrolateral, dorsolateral, and anterior prefrontal regions. Response selection in tasks requiring high attentional load is associated with activity in the intraparietal sulcus and bilateral frontal eye fields (Culham, Cavanagh, & Kanwisher, 2001).

In a study of multimodal imaging technique using MRI and DTI among 339 participants between ages 8 and 89, intracortical myelination indicated intra-individual variability on a speeded inhibition task across the lifespan (Grydeland, Walhovd, Tamnes, Westlye, & Fjell, 2013). Similar studies utilizing multimodal technique suggests that ACC is a significant predictor of cognitive control, especially among young children (Fjell et al., 2013; Velanova, Wheeler, & Luna, 2008; Walhovd et al., 2012). Increased activation in lateral and medial frontostriatal regions, along with neural connectivity during the inhibition and flexibility tasks (Rubia, 2014), is related to age-related progressive developmental changes in these regions. These findings collectively signify the relevance of temporoparietal, ACC, and dlPFC maturation for the development of several EF abilities in childhood. Wisconsin Card Sorting Test (WCST) administration among adolescents and adults has been shown to activate the dorsolateral prefrontal cortex (dlPFC), the ventromedial prefrontal cortex (vmPFC), and inferior parietal lobule (IPL; Alvarez & Emory, 2006). These findings have also been corroborated with the findings from patients in lesion studies (Stuss et al., 2000).

However, many tasks that assess these abilities fail to separate each component of EF, such as attention, inhibition, working memory, cognitive flexibility, and similar abilities, further complicating drawing linear association with the specific cortical structure or neural pathway. For instance, WCST which is a complex cognitive construct, is a measure that involves several aspects of EF, such as inhibition, perseveration, cognitive flexibility, stimulus differentiation, ability to incorporate feedback, and the like (Miyake et al., 2000).

ToM and EF

ToM and EF are two significant cognitive capabilities that begin developing during the preschool years (Garon, Bryson, & Smith, 2008; Wellman, Cross, & Watson, 2001). Difficulties and impairments in the faculties of executive controls and ToM are associated with a wide range of neurodevelopmental disorders and psychiatric conditions (Geurts, Verté, Oosterlaan, Roeyers, & Sergeant, 2004; Pilowsky, Yirmiya, Arbelle, & Mozes, 2000; Schenkel, Marlow-O'Connor, Moss, Sweeney, & Pavuluri, 2008). There are, however, mixed clinical findings regarding this association. For instance, an adult who sustained amygdala damage demonstrated EF deficits but intact ToM performance (Fine et al., 2001). Another study demonstrated that an individual with impaired orbitofrontal capacity showed no relationship between EF and ToM (Barch et al., 2005). Fine, Lumsden and Blair's (2001) and Lough, Gregory, and Hodges's (2001) studies demonstrated poor mentalizing abilities in the presence of unimpaired EF skills, while Bird, Castelli, Malik, Frith, and Husain (2004) in their clinical study found intact ToM abilities in the presence of impaired EF abilities. Although these findings suggest the independence of ToM abilities and EF skills, these studies fail to explain the contribution to ToM of varying EF abilities within the executive processes.

Several developmental studies have focused on studying ToM and EF together mainly because these abilities develop concurrently. Although numerous observational studies have established a significant association between ToM and several components of EF (Carlson, Moses, & Breton, 2002; Hughes, 1998), this relationship's nature remains unclear. Studies have repeatedly identified evidence for a strong association between EF and ToM (e.g., Ozonoff, Pennington, & Rogers, 1991; Sabbagh, Xu, Carlson, Moses, & Lee, 2006; Ozonoff & McEvoy, 1994). These studies, however, have generally relied upon correlational analysis to draw associations between ToM and EF abilities, or they have based their findings on the impairment patterns among known social dysfunctions such as autism or Asperger's Syndrome (e.g., Baron-Cohen, 1995; Charman & Baron-Cohen, 1995; Happé, 1994; Leslie & Thaiss, 1992).

Despite the dichotomy in considering ToM either a distinct domain of social cognitive processes or a construct that rely on general executive mechanisms, researchers have recognized that EF abilities substantially support mature mentalizing abilities. The following section outlines studies that have substantiated the ToM and EF association.

Domain-Specific Domain-General Argument of ToM and EF

Social reasoning theories, in particular ToM abilities, emphasize the equal contribution of both modular and non-modular components of performance among children (Leslie et al., 2004; Moses, 2001). Several clinical and non-clinical studies have identified a significant association between EF abilities and ToM. In their comprehensive review, Hughes and Graham (2002) highlighted that in a neurodevelopmental disorder, autism, not only are deficits in EF and ToM significant, these two abilities are dependent on one another. Another study (Fisher & Happé, 2005) indicated a significantly positive association between EF and ToM among two clinical groups of children. Both clinical groups, who received either EF or ToM training, did not demonstrate significant EF performance changes, but improvements on ToM task performance were observed on a follow-up for both groups regardless of their training. In a sample of children diagnosed with autism, working memory and inhibition were found to be positively associated with ToM (Joseph & Tager-Flusberg, 2004). Studies conducted on children with attentional and behavioral problems also suggested a significant association between ToM and EF (Fahie & Symons, 2003; Hughes, 1998). Similar findings emerged when the relationship between ToM and EF was explored in the non-clinical population (e.g., Cole & Mitchell, 2000; Gordon &

Olson, 1998), indicating a positive association between ToM and planning, cognitive flexibility, and inhibition (Sabbagh et al., 2006).

Conversely, some researchers have questioned the association between ToM and EF abilities. A study (Perner, Kain, & Barchfeld, 2002) found that children at risk of ADHD displayed impaired performance on several EF tasks but showed no impairments on advanced ToM tasks, which is against the assumption that ToM relies on executive controls. Emphasizing the lack of association between EF and ToM, children with autism, on the other hand, show intact performance on EF domains that include planning, set-shifting, and inhibition, but show deficits on false belief tasks assessing ToM (Pellicano, 2007). Furthermore, research has suggested that EF skill training shows improvements in ToM at follow-ups, but targeting ToM shows no significant improvements in EF (Fisher & Happé, 2005).

As outlined above, most of the studies relating EF and ToM have examined children (e.g., Cole & Mitchell, 2000; Fahie & Symons, 2003; Fisher & Happé, 2005). There are several limitations to working with children for this purpose. First, children are in their early developmental stages, and neither ToM nor EF abilities are fully developed until late adolescence (Anderson et al., 2002; Brune & Brune-Cohrs, 2006), which aligns with cortical development (Diamond, 2001; Gibson & Petersen, 1991). Cognitive and neural development occurs in stages with essential cognitive functions emerging first followed by social cognitive abilities later in childhood (Diamond, 2001; Gibson, & Petersen, 1991). Apperly et al. (2009) emphasized the importance of exploring different EF abilities to understand their contribution to maintaining ToM in adulthood. According to these authors, EFs likely play a crucial role in the development of ToM, though it may not be significant in maturely developed ToM abilities in adulthood.

The literature on social-cognitive understanding among adults has shifted from a strict domain-specific approach to a view of social cognitive processes involving both modular and domain-general processes of EF abilities (e.g., Leslie, Friedman, & German, 2004; Leslie, German, & Pollizi, 2005). Recent evidence has suggested that modular structure underlies ToM abilities while separate EF components facilitate specific, distinct mentalizing processes (e.g., Decety & Somerville, 2003; Harari, Shamay-Tsoory, Ravid, & Levkovitz, 2010). Performance on specific tasks such as second-order false belief ToM measures and story-making tasks requires simultaneous consideration of the information presented. This requires EF functions involved in holding a piece of information in mind and assimilating and incorporating new information to select situationally relevant responses. These tasks rely heavily on cognitive resources such as inhibition and working memory that mediate the cognitive load by holding multiple perspectives of different individuals (X thinks that Y feels stressed) and manipulating and integrating different pieces of information to compare and contrast various views.

Perhaps the domain-specific/domain-general argument is complex. Empirical studies have either emphasized domain generalizability or domain specificity of ToM. In contrast, other studies have attempted to draw conclusions about EF abilities and mentalizing processes associations by proposing that these processes appear to exist on a continuum. A dichotomous explanation and ill-defined study methodologies likely limit the dynamic investigation of these abilities since performance is task-dependent, and not domain-dependent. The following section compares and contrasts theoretical assumptions regarding EF and ToM association.

Theories of ToM and EF Relationship

Perner and Lang (1999) highlighted some theoretical perspectives regarding the relationship between ToM and EF. Three theories have been the source of current debate based on the assumption that (1) ToM relies on EF, (2) EF relies on ToM, or (3) EF and ToM are interdependent and share associated brain regions and neurophysiology.

The primary underlying postulation behind the first proposal, ToM's dependence on EF, suggests that skills such as inhibitory control and self-monitoring are essential abilities to recognize mental states within oneself and infer others' mental states (Carlson & Moses, 2001). Following a similar assumption, Russell (2003) postulated that executive control of self-monitoring is a precursor for self-awareness, which is essential for understanding ToM. Similarly, the ability to inhibit one's perspective and shift the focus on others' mental states is equally relevant for a mature ToM. ToM's reliance on EF has been extensively covered in longitudinal studies that indicate that the presence of EF strongly predicts ToM in childhood (Carlson, Mandell, & Williams, 2004; Hammond et al., 2012; Hughes & Ensor, 2007; Marcovitch et al., 2015; Müller et al., 2012). In one longitudinal study, Hughes (1998) determined that EF predicted ToM over time among children; however, ToM did not predict EF over time.

The second proposal suggests that EF relies on ToM and posits that an individual requires an awareness of self and others to control their behaviors and actions purposefully. For effectively exercising inhibitory controls, a child is required to appreciate their social context to modify behaviors and exert self-control over intrusive tendencies by acknowledging that mental representations influence our behaviors (Lang & Perner, 2002; Perner & Lang, 1999; Perner, Stummer, & Lang, 1999). This implies that a child can identify himself/herself as distinct from others and have the fundamental appreciation for the relation and difference between behaviors and mental states, with mental states being the agent to drive their behaviors. Children's self-awareness and the awareness that our beliefs drive behaviors provide the foundation and act as the precursor for modifying thoughts and actions. This relationship between the early development of ToM preceding and predicting later EF has been favorably highlighted in several studies (e.g., Hughes & Ensor, 2007; McAlister & Peterson, 2013; Müller et al., 2012; Wade, Browne, Plamondon, Daniel, & Jenkins, 2016).

Lastly, according to the third proposed theory, ToM and EF abilities are reciprocally related since they share common neural networks. The coexisting ToM and EF impairment among children with various neurocognitive dysfunctions, and shared neural networks, specifically prefrontal cortical regions, corroborate that ToM and EF abilities rely on each other (Ellis & Gunter, 1999; Ozonoff, Pennington, & Rogers, 1991). For instance, Austin, Groppe, and Elsner (2014) in their 1-year longitudinal study explored the association between ToM and distinct EF abilities (attention, set-shifting, working memory and inhibition) in middle childhood (T1 between ages 6 and 11 and T2 between ages 7 and 12 years). These investigators found a small but significant correlation between all components of EF and ToM where executive control was associated with a better understanding of mental states at both T1 and T2, in particular, between EF components of working memory and attention shifting (controlling for age, gender, and fluid intelligence). This and several other studies further corroborate that these abilities are likely to be reciprocally predictive of each other (Austin, Groppe, & Elsner, 2014; Calderon et al., 2010; Hughes & Ensor, 2007; Müller et al., 2012; Perner et al., 2002).

ToM is unique since the capacity to mentalize beliefs and thoughts about self and others presents different cognitive demands mediated by diverse cognitive processes such as EF abilities. It can be argued that ToM is an innate modulatory function (Baron-Cohen,1998). However, since development in neurotypical individuals unfolds in stages, individuals progressively exhibit mature theory of mind abilities as executive controls are not developed until late adolescence. It is debatable if ToM is a domain-specific modular process, or its development is tangential to executive controls. ToM relies on EF abilities to create output by organizing relevant information for situationally appropriate mentalizing conceptualization (Leslie et al., 2004).

ToM and The Contribution of Relevant EF Ability to Task Performance

Only a few studies have explored specific EF abilities and their contributions to performing the ToM task among adults. Some studies have indicated that inhibition and working memory explain the strongest association with ToM (e.g., Carlson et al., 2004). In this regard, EF abilities provide a foundation that serves as a prerequisite for the construction of a belief concept to carry out a function such as distancing oneself from the situation, reflecting on the thoughts and behaviors, and inhibiting spontaneous, biased knowledge about another individual (Carlson & Moses, 2001). Nonetheless, not every task requires complex executive abilities that are necessary to perform ToM tasks successfully.

According to Ahmed and Miller (2011), exploring the association between ToM and EF can lead to a better insight into underlying ToM task mechanisms. A study conducted by them examined the relationship between faculties of EF and ToM using a measure of EF and three measures of ToM that consisted of the Reading the Mind in the Eyes task (RME), Strange Stories and Faux Pas Test. RME asks participants to view the eye region's photographs and match the specific emotion (e.g., surprised) with the correct picture (see Appendix A for a comprehensive list of ToM tasks). They utilized D-KEFS executive function system measuring cognitive flexibility, verbal and motor fluency, inhibition, problem solving, deductive reasoning, planning and verbal abstraction. The study found that the EF predictors varied by the ToM test and nature of the ability it examined. None of the EF tasks explained significant variability in

RME performance, while verbal fluency and deductive reasoning showed significant association with Strange Stories Test. Furthermore, verbal fluency, and problem-solving demonstrated significant variability on Faux Pas test. The authors concluded that each task measuring ToM utilized different and variable EF abilities.

A different study conducted by Bull, Philips, and Conway (2008) in undergraduate students (*M* = 19.16 years, *SD* = 2.57) explored the role of dual-task manipulation; simultaneous presentation of 2-Back and ToM tasks. Dual task relied on executive control that utilized switching, updating, and inhibition abilities to examine their performance on tasks of mental state and non-mental state. ToM tasks consisted of a modified ToM story task with multiple choice mental state questions (Channon & Crawford, 2000; Happé, 1994; Stone et al., 1998), and the Reading the Mind in the Eyes (RME; Baron-Cohen et al., 2001a) and all the control tasks that included a story-based task about physical/mechanical events with comparable multiple-choice response set and control eye region task with age and gender revealed by the eyes. Their study design was comprised of five conditions. The first group completed all ToM tasks and control tasks under single task condition. The other groups completed ToM tasks and control tasks paired with either EF inhibition task, (a NO GO task variant; Klingberg & Roland, 1997), EF switching task (Rende, Ramsberger, & Miyake, 2002), or EF updating task (1-Back working memory task variant; Braver et al., 1997). Bull et al.'s (2008) analysis showed that participants performed more accurately on the ToM eye task under single administration than when the ToM task was paired with an inhibition task. However, no significant difference was observed between single administration performance and dual performance when the ToM eye task was paired with switching and updating tasks. Nevertheless, dual task presentation significantly influenced the performance on the story-based tasks for both ToM stories and control story task condition in comparison to single task performance. Performance did not differ significantly from one EF task to the other. This study indicates that regardless of the nature of the story, story-based tasks are more demanding than the emotion recognition task. Additionally, performance on the emotion recognition task was negatively influenced when paired with an inhibition task rather than working memory or task-switching performance.

A subsequent analysis was performed by Bull et al. (2008) to explain the significance of inhibitory processes to perform ToM tasks by assessing participants on the RME task. The RME task minimizes the delays associated with the demands on linguistic/comprehension abilities, the requirement to process multiple perspectives simultaneously, or follow the sequence of events by asking participants to select appropriate mental state terms from the provided responses after looking at the images of the eye region. The results revealed a significant drop in participants' performance on the RME task [$t(53) = 2.34$, $p = 0.02$] under dual task conditions, while performance on the Eyes Control task under dual task conditions remained unimpaired [$t(53) = 0.60$, $p = 0.60$], suggesting that the ToM skills, as measured through RME task performance, are not spontaneous. This study underlines the significance of inhibitory cognitive mechanisms for performing ToM tasks for selecting appropriate responses by overriding personal attributes and spontaneously activated responses to an image's features. They demonstrated that the interference mechanism between ToM RME task and EF inhibition is related to the inhibitory processes required to perform mentalizing tasks beyond the general attentional demands.

In contrast, interference on verbal tasks occurred on both mental and non-mental state representation tasks and across all executive abilities used in the study. Bull et al. (2008) concluded that interference on the ToM task was influenced since ToM and EF abilities share attentional reserves. Additionally, the authors highlighted that the dual-task interfered more with the Stories task in comparison to the Eyes task. Bull et al. (2008) related this difference to the complex nature of mental state reasoning and comparison of multiple mental state and belief perspectives required to perform Stories task. Additionally, the performance deterioration on both ToM stories and control stories under the dual-task conditions indicated depleted attentional resources rather than overlapping EF and ToM abilities. A decline in the control Stories task and not only the ToM Stories task indicates that dual task (switching back and forth between EF and Stories task) draws on the cognitive processes that are not limited to solely mental state reasoning per se (Bull et al., 2008).

These reasons question the claim of the previously found associations between EF and ToM abilities overlap. As explained above, the story task relies heavily on simultaneous multiple perspective evaluation to generate narratives. Conclusions drawn from the Bull et al. (2008) suggest that executive demands are not only amplified due to mentalizing demands, but also due to cognitive strains of task comprehension, and attentional and working memory requirements of a story-based task (Lough et al., 2006).

German and Hehman’s (2006) study also supported the association between EF and ToM tasks and indicated that excessive demands on the executive cognitive control functions of inhibition and processing speed interfere with ToM performance in both typically developed younger and older adults. Similar results were identified when McKinnon and Moscovitch (2007) assessed ToM performance among younger and older adults and indicated that the ToM tasks varied depending on the recruited EF abilities. The author specified that ToM performance decreases as the cognitive load on EF abilities (for example, working memory) increases.

According to Carlson et al. (2002), EF abilities of inhibition and working memory, and not planning abilities, share a strong relationship with ToM abilities. EF abilities of inhibition and working memory share the strongest association with ToM (Carlson et al., 2002; German & Hehman, 2006). In their analysis, German and Hehman (2006) demonstrated that performance on ToM tasks suffers among children and adults due to increasing cognitive demands. They highlighted that processing speed and inhibitory control play a crucial role in performing ToM tasks. These authors also suggested that deficits in EF abilities likely explain impaired ToM performance rather than specific deficits in ToM mechanisms. McKinnon and Moscovitch (2007) also assessed ToM and EF abilities among older and younger adults and found that performance on the ToM task is dependent on EF abilities; ToM performance decreases as the demands on the EF function increases.

Inhibitory processes are paramount in performing ToM tasks to suppress the spontaneous first impression and produce a more conscious effortful mental state-related response. Hence, according to these studies, the tasks designed to assess mental states and non-mental states share similar association with EF abilities, highlighting that general cognitive processing demand, rather than mental state inference demands of ToM tasks, is more implicated in explaining the shared variance in accuracy and response latency (Apperly, Samson, Chiavarino, & Humphreys, 2004; German & Hehman, 2006).

ToM, EF and the Developing Brain

To understand the temporal nature of ToM and EF development, a review of normative brain development can help illuminate the nature of their relationship by exploring the development of brain regions and networks implicated to support these abilities. By exploring the cerebral structures and neural networks, researchers can gain insight regarding whether one ability precedes the other during the developmental stages or possibly one ability is either structurally or functionally significant for the development of the other skill. It is also likely that the developmental maturation of cortical regions instigates and evolves both processes simultaneously, or both ToM and EF abilities likely share common neural structure/network, but they also rely on domain-general regions. Outlining a typical brain development is crucial to identify the temporal onset and trajectories relevant to neural development in regions associated with ToM and EF and their interconnection during the initial stages of development.

A newborn brain is approximately one third the size of that of a human adult. It continues to grow as per genetic and environmental influences, with brain maturation occurring throughout childhood until early adulthood (Toga, Thompson, & Sowell, 2006). Cerebral growth after birth follows distinctive patterns at different rates (Giedd & Rapoport, 2010). Studies indicate that brain structures responsible for primary functions develop first, followed by regions responsible for higher-order functioning. For example, the visual cortex is matured by approximately four months of age. However, the medial prefrontal cortex, a region relevant to ToM and EF abilities, develops at 3 to 4 years of age.

In a longitudinal study, Gogtay et al. (2004) discovered that cortical development followed a pattern where sensorimotor, frontal, and occipital poles matured first, followed by parietal regions involved in language and spatial orientation and then the frontal lobes implicated in mental reasoning abilities and executive controls. Notably, the prefrontal and inferior parietal cortex and superior temporal cortex, which are implicated in integrating primary functions, mature last and continue to develop throughout late adolescence (Apperly et al., 2004). The region implicated in both ToM and EF, the medial prefrontal cortex, shows maximal development at around 3 to 4 years of age (Huttenlocher, 1979). Studies have also demonstrated that the fastest growth in frontal networks supporting goal-directed behaviors occurs from 3 to 6 years of age (Chugani, Phelps, & Mazziotta, 1987; Thompson et al., 2000), and continues to mature at 11 years of age (Sowell et al., 2004).

These developmental studies are fascinating, given that not only do ToM and EF show substantial changes during these years (Zelazo et al., 2003), but they are also linked to prefrontal functioning. Although neural development coincides with the development of social cognitive abilities and EFs, a well-defined mapping of cortical development onto cognitive and behavior functions is impossible without precise measures of neural association, EF, and ToM being assessed within the same sample. Given this limitation, most of the studies have relied on cross-sectional analysis and reverse inferences (Poldrack, 2011) for arriving at certain conclusions for exploring the relationship between EF and ToM abilities in the field of neuroscience.

Wade et al. (2018), in their theoretical review, outlined the path of cortical development and identified distinctive and shared regions of the brain that are implicated in performing ToM tasks, EF tasks, and shared neurological correlates of ToM and EF skills among children. The authors specifically delineated false belief tasks and “top-down” EF abilities that include inhibition, working memory, and cognitive flexibility. Some neuroimaging studies have relied on the “cognitive function networks” (CFNs; Davis et al., 2017) comprising discrete brain regions and neural pathways when a particular task is performed. The most common approaches for exploring the relationship between ToM skills and EF abilities and their associated cortical regions and neural mechanisms during task performance include electroencephalography (EEG), event-related potentials (ERPs), structural magnetic resonance imaging (MRI), and functional magnetic resonance imaging (fMRI), diffusion imaging (dMRI or DTI), and functional near-infrared spectroscopy (fNIRS). The following sections briefly outline imaging studies that identified brain regions associated with the constructs of ToM and EF abilities.

ToM Brain Regions

Theories that rely on domain specificity of ToM abilities draw their conclusions from neuroimaging studies. Neuroimaging studies have highlighted several brain regions recruited consistently during ToM performance. These include bilateral TPJ, in particular, the inferior parietal lobe at the junction of the posterior temporal cortex, the medial prefrontal cortex with the anterior paracingulate cortex, precuneus/posterior cingulate cortex, and superior temporal sulcus/medial temporal gyrus (Amodio & Frith, 2006; Decety & Sommerville, 2003; Gallagher & Frith, 2003; Saxe & Kanwisher, 2003; Völlm et al., 2006). Meta-analytic studies on brain regions have supported the coordinated input from frontal-temporal-parietal cognitive function network that collaborates to register other's beliefs, intentions, desires, and goals (Molenberghs, Johnson, Henry, & Mattingley, 2016; Schurz, Radua, Aichhorn, Richlan, & Perner, 2014).

Some findings highlight the crucial role of the prefrontal cortex (PFC) in ToM development and expression (e.g., Meinhardt, Kühn-Popp, Sommer, & Sodian, 2012). These studies support the domain specificity of ToM at the cortical level rather than reliance on EF and suggest a dedicated ToM neural circuit. An EEG study conducted in children (4-year-olds) localized the dorsomedial prefrontal cortex (dmPFC) and right TPJ to be positively associated with person-specific ToM after controlling for executive processes of inhibitory control and shift abilities (Sabbagh, Bowman, Evraire, & Ito, 2009). Similar observations were made on ERP studies comparing adults and 4 to 6-year-old children suggesting a significant association between prefrontal activity and mentalizing abilities (Liu, Sabbagh, Gehring, & Wellman, 2009).

Bowman, Liu, Meltzoff, and Wellman (2012), in their ERP study in 7- and 8-years old children, provided a developmental comparison by replicating the study stimuli and the methodology used in Liu et al.'s (2009) adult ERP study. Their analyses revealed midfrontal scalp activation associated with both belief and desire reasoning, parallel to adults' findings in Liu et al.'s (2009) study. Moreover, belief reasoning demonstrated selective right-posterior scalp activation in children. These findings highlight that by the age of 7 years, mentalizing processes engage neural activity that depicts adult-like neural processes, thus, highlighting the ToM activity related to developmental neural maturity. Additionally, these neural substrates in the midfrontal region corroborate the assumption that specific neural pathways are recruited for mental-state reasoning abilities. Similar assumptions regarding the substrate specificity have been shown after controlling for domain-general abilities of executive functioning for four-year-old children (Sabbagh et al., 2009).

Although neuroimaging studies in children are limited, they also support a cognitive functioning network that involves TPJ, mPFC, posterior cingulate cortex (PCC)/precuneus, and superior temporal sulcus (STS)/ middle temporal gyrus (MTG) in children between ages 6 and 12 (Kobayashi, Glover, & Temple, 2007; Sommer et al., 2010). Wiesmann, Schreiber, Singer, Steinbeis, and Friederici (2017) utilized diffusion-weighted MRI and demonstrated that performance on false belief tasks depicted age-dependent changes in the TPJ, mPFC, precuneus, and MTG regions among 3 to 4-year-old children. The authors indicated that activation in these regions was independent of language abilities, and suggested a distinct neural circuit in ToM among children. The authors suggested that age-dependent white matter maturation and increased connectivity between temporoparietal and inferior frontal gyrus (IFG) regions strengthen ToM skills among pre-schoolers. Moreover, Gweon, Dodell-Feder, Bedny, and Saxe (2012) used FMRI in children between 5 and 11 to demonstrate increased activation but progressive selectivity in the bilateral TPJ region associated with reasoning about mental states.

Billeke and Aboitiz (2013) comprehensively reviewed the mechanisms of social information processing in adults and identified several cortical regions associated with social cognitive processes. The authors identified the distinctive brain regions of social cognitive processes that included social perception, emotion and motivation recognition, behavioral adaptation, and social attribution (see Appendix D). They elaborated that social cognitive processes should best be viewed as a dynamic system rather than isolated mechanisms of social cognitive abilities. Similarly, another meta-analysis review (Schurz & Perner, 2015) identified that mPFC is activated during the tasks of mental state reflection while activity in the posterior Superior Temporal Sulcus (pSTS) is reflective of actions and overt mental state representations.

Schurz et al. (2014), in their meta-analysis, included a diverse range of experimental tasks along with the associated cortical regions identified by the investigators. Some of the tasks these authors identified comprised false belief task (Saxe & Kanwisher, 2003), trait judgments task (Mitchell et al., 2002), strategic games (Kircher et al., 2009), social animations (Castelli et al., 2000), mind in the eyes (Baron-Cohen et al., 1999) and rational actions (Brunet et al., 2000; see Schurz et al., 2014 for a review). Schurz and Perner (2015) elaborated that each task utilized in the imaging studies mirrored the ToM construct's different operationalizations. They warned against using the umbrella term of ToM and emphasized the significance of refining specific ToM components to facilitate improved mapping of cortical regions (e.g., activation within specific TPJ and mPFC regions). Although imaging studies have highlighted the significance of a dedicated network implicated in ToM even after controlling for some EF abilities, EF and shared networks that participate in both EF and ToM activities among adults cannot be ignored.

ToM and EF Shared Neural Correlates

The proponents of domain-general processes have implicated several brain regions with both ToM and EF abilities (see Appendix E). The conclusions drawn from the meta-analysis findings of EF abilities and relevant brain regions in children and adults (e.g., Alvarez & Emory, 2006; Houdé, Rossi, Lubin, & Joliot, 2010; Wager, Jonides, & Reading, 2004) have recognized several brain areas frequently associated with ToM. These brain areas include anterior insula (Lamm & Singer, 2010), IPL (Decety & Sommerville, 2003; Uddin, Molnar-Szakacs, Zaidel, & Iacoboni, 2006), temporoparietal regions (Scholz et al., 2009) and vmPFC (Shamay-Tsoory, Tibi-Elhanany, & Aharon-Peretz, 2006). The dmPFC region has been identified as a salient region for both inhibitory control and ToM skills (Dodell-Feder, Koster-Hale, Bedny, & Saxe, 2011; Simmonds, Pekar, & Mostofsky, 2008). Apart from TPJ's role in ToM, it has also been implemented in attention, inhibiting, switching, and redirecting attention (Corbetta, Patel, & Shulman, 2008).

Self-perspective and basic response inhibition appear to share a neural mechanism along with ToM specific recruited brain regions. Van der Meer, Groenewold, Nolen, Pijnenborg, and Aleman (2011) in their fMRI study in undergraduate students (N = 19), assessed ToM abilities using movie clips adapted from Samson et al. (2004, 2005) and Apperly et al. (2004).

Their analysis revealed bilateral activation in the IFG, dmPFC, and insula region when participants performed high (self-perspective inhibition) versus low-inhibition (stop-signal) tasks, and ToM recruited left STG, MTG supramarginal gyrus, TPJ, and precuneus. Their findings align with the studies that suggested that variations in the ToM performance can be viewed in the light of working memory demands (Bull et al., 2008; McKinnon & Moscovitch, 2007).

Some similarities and differences can be observed in empirical literature between EF and ToM cortical regions. Van der Meer et al.'s (2011) study demonstrated that ToM formed superior temporal gyrus (STG), MTG, TPJ, and precuneus circuitry, whereas a high versus low inhibition belief reasoning task and a stop signal task activated IFG. The authors further stated that the insula region is significant for the awareness of self-related information (Craig, 2009), and decreased activation of this region has been associated with impairment in self-generated and other generated stimulus discrimination (Allen et al., 2004). Van der Meer et al.'s (2011) study concluded that perspective-taking abilities and executive functions, in particular, cognitive inhibition, are mutually dependent, and inhibitory processes precede perspective-taking processes. Van der Meer et al.'s (2013) subsequent comparative study between high and low psychosis prone undergraduate students indicated increased activation in the left IFG among high psychosis prone individuals on a ToM self-perspective inhibition task. High psychosis prone and low psychosis prone individuals performed equally well on the primary inhibition task, which suggests that self-perspective inhibition demands more cognitive resources and appears to be more effortful. These findings suggest that EF abilities are required to inhibit self-perspective (Bull et al., 2008; McKinnon & Moscovitch, 2007).

The association between belief attribution and inhibitory control can likely be implicated in brain regions and functions associated with domain-general cognitive processes. As highlighted above, the inhibitory functions are crucial for inhibiting self-perspective, which further facilitates performance on second-order false belief tasks. Saxe, Schulz, and Jiang's (2006b), fMRI study among adults concluded that EF abilities are recruited to form the mental representation of others needed for ToM. The investigators conducted a series of experiments by utilizing the false-belief task and EF tasks that required only response selection to match the task demands for both the abilities. Their investigation indicated shared neural activity in the bilateral parietal sulcus, mPFC, ACC, and left TPJ (activated only during the false belief task performance). Their findings concluded that ToM skills recruit several EF abilities that include attention, inhibition, and response selection, including regions that facilitate representation of others' thoughts and beliefs (false-belief task) such as TPJ, and to a lesser extent, mPFC and PCC. Saxe et al. 's (2006b) findings favored that EF abilities facilitate ToM understanding.

To minimize the influence of verbal processes, Rothmayr et al. (2011) investigated ToM and EF neural correlates using nonverbal visual false belief tasks and inhibitory controls using visually identical stimuli in an fMRI study. Their results identified a distinct activation pattern for belief reasoning and inhibitory function along with significant overlap observed in the right TPJ, right superior dmPFC, dorsal part of the left TPJ, and lateral prefrontal areas. The authors suggested that neither TPJ nor dmPFC areas are limited to only social-cognitive skills because dmPFC, dlTPJ, and lateral prefrontal regions are also associated with memory functions (Cabeza & Nyberg, 2000). Nonetheless, the notion that some of the brain regions are independently recruited for domain-general EF and ToM skills suggests that even if these skills share a mutual network, the regions recruited by ToM and EF are not entirely overlapping.

Performance on several ToM tasks requires EF neural underpinnings of working memory, attention, inhibition, and response selection (Saxe, Moran, Scholz, & Gabrieli, 2006a; Saxe et al., 2006b). In this case, TPJ and vlPFC support domain-general processes of selective attention and inhibition (e.g., Mitchell, 2009; Rothmayr et al., 2011), mainly when differences between perspectives exist. Leslie and colleagues (2005) specified that the "selection processor" of executive attentional control supports belief and desire reasoning, mediated through ACC, a region known to play a crucial role in supporting social cognitive processes (Amodio & Frith, 2006; Lieberman, 2007). More specifically, dorsal ACC supports monitoring and error detection while the rostral-ventral area processes motivational or emotional knowledge (Amodio & Frith, 2006; Bush et al., 2000; Devinsky et al., 1995).

In conclusion, several meta-analysis findings have identified brain regions implicated in domain-general EF (Alvarez & Emory, 2006; Houdé, Rossi, Lubin, & Joliot, 2010; Wager, Jonides, & Reading, 2004) that are also usually associated with ToM tasks. These regions include IPL (Decety & Sommerville, 2003; Uddin et al., 2006), vmPFC (Shamay-Tsoory, Tibi-Elhanany, & Aharon-Peretz, 2006), temporoparietal regions (Saxe et al., 2009), and anterior insula (especially in understanding feeling states; see Lamm & Singer, 2010). The dmPFC region is also implicated in ToM and inhibitory control, but in separate studies (Dodell-Feder, Koster-Hale, Bedny, & Saxe, 2011; Simmonds, Pekar, & Mostofsky, 2008). The region of TPJ is regarded as the "circuit breaker" for the attentional control, implemented in disengagement and attentional reorientation (Corbetta, Patel, & Shulman, 2008). To sum up, these conclusions are drawn across multiple studies and any observed cortical changes could be explained in the context of a given task, or extraneous cognitive function required to perform the specific task in a given experimental design (Wade et al., 2018).

Having established the relationship between ToM and EF abilities from a neurological standpoint, the following sections will draw conclusions about developmental and performance correlates of ToM. Social cognitive development is an enduring process of change unfolding throughout developmental years as new ToM concepts continue to emerge until adulthood. With maturation, individuals acquire adaptive problem-solving, compromising, and perspective-taking skills that are part of their healthy maturational process (e.g., Sandy & Cochran 2000). These conclusions are also corroborated by neurological research, suggesting that continued growth in critical brain areas leads to an increase in perspective-taking (Crone & Dahl, 2012), facilitated by increased social interpersonal interactions across ages.

Development and Measurement of ToM

ToM is believed to be an innate ability. However, like any other cognitive skill, it requires other supporting abilities such as language, social interactions, and repeated but variable experiences to mature its development. Not surprisingly, ToM development advances with age (Wellman et al., 2001). Much work in ToM has been generated from the studies conducted in early childhood predominantly with preschool children (e.g., Gergely, Bekkering, & Kiraly, 2002) and young children (Bryan & Gast, 2000). However, the age at which ToM ability develops has been scrutinized in literature.

Attempts have been made to use simplified implicit, non-verbal tasks to assess preverbal infants, suggesting that some ToM abilities are present in infancy and earlier stages of development. For example, Kristen et al. (2011) in their longitudinal study assessed children at the age of 7 to 18 months to assess "mental state language." The investigators demonstrated that children as young as 15 months of age exhibit understanding of intentions on the tasks of intention-based imitation of behaviors, and at 24- and 36-months, expectation violations, and use of cognition vocabularies (e.g., think, want, see). Other accounts also suggest that by 14 months, children can comprehend a true belief task and by 18 months, they display some sensitivity to another person's visual gaze. This sensitivity can be observed using eye tracking change-of-location experiments as children have faster reaction times on the object location congruent trials compared to object location incongruent trials. (Repacholi & Gopnik, 1997; van Rooijen et al., 2018; Yott & Poulin-Dubois, 2016).

However, these conclusions are questionable due to the presence of extraneous variables (Slaughter, 2015), differences in conceptualization and theorization of ToM (Sabbagh & Paulus, 2018; Scott & Baillargeon, 2017) and a lack of supporting psychometric information

(Dörrenberg et al., 2018; Kulke et al., 2018). Despite the use of sophisticated tools and the assessment measures to advance our understanding of ToM, empirical literature has been unsuccessful in drawing robust conclusions about its mature development.

Some psychologists argue that ToM ability does not develop until the age of four (Gopnik & Wellman, 1994). Other experts, on the other hand, claim that the emergence of ToM abilities is evident before the age of four (Meltzoff & Prinz, 2002; Stich & Nichols, 1995), and that development is observed between two to five years of age. Stich and Nichols (1995) explained that before the age of four, children start to exhibit an understanding of others' intentions. However, they assert that ToM ability starts to develop between the ages four and five, which further attests to the claims that ToM does not develop before the age of four. Before the age of 7, a child cannot comprehend how an individual will perceive a three-dimensional model of three mountains from a different angle other than the child's perspective (Piaget & Inhelder, 1956; Surtees & Apperly, 2012).

Piaget's work on sensorimotor development explored an infant's interaction with the physical world that gradually develops and increases in complexity as the demands of the practical world knowledge increase. Through this process, a child overcomes egocentric understanding and starts beginning to demonstrate understanding of others' perspectives with repeated experiences supported by social interactions in their environment. Elkind (1967) explained that the incapability to differentiate subjective schemas and experiences from objective reality and the inability to comprehend the standpoint of others compared to their own is called "egocentrism" (Artar, 2007). In egocentric mental representations, the self is the focus of every perspective. A person may demonstrate inability to consider another individual's perspective, view, or opinion different from their own, and the frame of reference is on the self. For example, on Piaget and Inhelder's (1948) three mountains problem, children up to the age of seven lack appreciation for the other's perspective and choose images from their vantage point when ask to identify images as seen from observer's view. Piaget (1972) theorized and demonstrated that a child, however, learns to gaze, exhibits the ability to engage in pretend play, and realizes that another individual can have a different perspective than theirs.

Beyond the age of 5, in Piaget's theory of cognitive development, the third stage is called the concrete operational stage. The ability to take the perspective of others emerges as a part of the maturational process long after children can distinguish their thoughts and feelings from others' (Piaget, 1972). Between the age of 7 to 12, a child starts demonstrating increased use of logic. One of the abilities a child acquires during this stage is the capacity to consider multiple aspects of a situation. The ability to think from multiple perspectives emerges when a child can integrate thoughts and feelings with others' perspectives before acting prematurely. Integrating thoughts and feelings becomes accessible as a characteristic of cognitive maturation and development (Van der Graaff et al., 2014).

ToM ability has a developmental course (Kovács, Téglás, & Endress, 2010), and it varies in complexity from the ability to see, perceive, and recognize from a different physical perspective to a multifaceted understanding of others' intentions and beliefs (McHugh, Barnes-Holmes, & Barnes-Holmes, 2004). Nevertheless, there are other psychologists (for a review, see Carpendale & Lewis, 2006) who claim that the ToM ability is context and task-dependent, and people may exhibit this ability inconsistently. It is not surprising that diverse definitions and conceptualizations of ToM have given rise to a wide variety of measures. According to Carpendale and Lewis (2006), the acquisition of social understanding is less dependent on age than it is on the task designed to assess and measure such ability. However, the task and the nature of task complexity, and hence, perspective-taking, may be less demanding in some situations and more taxing in more complex circumstances. A diverse range of measures (outlined below) indicate that ToM has broader and nuanced developmental progression (Liddle & Nettle, 2006; Wellman et al., 2001).

Measuring ToM in Children

As explained earlier, the most frequently used measure to assess the ToM abilities in both typically and atypically developed individuals is the False Belief task (Brewer, 1991). False belief paradigm has been used as a gold standard to study ToM. This task requires an individual to attend to a situation that involves a specific scenario in which the reality states are different from the belief state, and attempts are made to make a clear distinction between self-belief state and other-belief state. Perner, Leekham, and Wimmer (1987) designed the first false-belief task that assessed children's self and other belief attribution abilities called the "Smarties task." This task required children to guess the contents of a box labeled "Smarties" by looking at only the outside. When children responded, "sweets," they were presented the opened box, which contained pencils. After re-hiding the pencils in the box, children were asked what they actually thought was in the box (self-oriented belief attribution). Children are then asked what their teacher, who has not seen the contents of the box, would say about the contents of the box (other-oriented belief attribution), and what is actually in the box (reality test).

The false belief model was proposed by Wimmer and Perner (1983), but this paradigm has gained popularity in ToM literature and has been used in a variety of contexts since then (Wellman et al., 2001). The scenarios shown in this task present a different state between reality and the character's beliefs. For example, the Sally and Anne Test (Baron-Cohen et al., 1985; Wimmer & Perner 1983) utilizes change of location scenarios where a doll character hides an object (location change task), and another doll character who saw this exits the room. The first doll then moves the object to another location. Participants are asked where they believe the doll that left the room will search for the object on returning. Presumably, this task requires an understanding (ToM) by participants to recognize that other characters who were not present in the room when the object was moved, will likely look for the object at its original location since they have no knowledge that the object was moved once they left the room (Brüne & Brüne - Cohrs, 2005). Through this task, the investigators sample a child's ability to differentiate the reality and a hypothetical state of mind (theory) of another individual or character in context.

Similarly, converging evidence has emerged from Smarties task (a content-change task) and similar false-belief paradigm (location-change task) studies that indicate a developmental course of ToM (e.g., Gopnik & Astington, 1988; Williams & Happé, 2010; Wimmer & Perner, 1983). These studies have suggested that children start demonstrating social cognitive maturity quite an early age (between ages 3 and 5) while some researchers warn against such claims and emphasize that false belief tasks measure narrow component of social cognitive maturity. Nonetheless, researchers have designed several tasks to capture the developmental pattern of perspective-taking and metacognitive progression across ages.

First Order ToM Tasks

First order functioning in the ToM ability represents thinking about another's mental states from first-person perspective about second-person perspective. As explained above, false belief paradigm (e.g., Sally-Anne Task, Smarties Task) requires participants to recognize someone else's belief when differing from their own beliefs (Sally thinks that that box has candies, when in fact, the box has pencils). These tasks investigate the first-order ToM, which is the ability to understand someone's belief about the state of a situation. There are mixed findings regarding the age by which a child typically starts demonstrating the presence of ToM. Some researchers have claimed that after 3 years of age, a child can complete a false belief task (e.g., Wellman et al., 2001), which aligns with the presumed developmental stage at which ToM begins to develop. However, other investigators noted that children start to show rapid growth at around four years of age and can successfully recognize diverse mental states of other people and draw inferences from their beliefs. For example, similar to Smarties task, children can appreciate that only they know that there are pencils in the box, but someone unaware of the inside contents would believe that the box contains sweets (Doherty, 2009; Perner et al., 1987; Wellman, Cross, & Watson, 2001; Wimmer & Perner, 1983). This simultaneous emergence of these developmentally expected and adaptive abilities suggests the emergence of the ToM mechanism with no clear distinctive understanding between self and other-oriented belief attribution abilities. Proponents of complex ToM measures (e.g., Liddle & Nettle, 2006) have highlighted that ToM ability development is an enduring process that continues to develop after five years of age. For instance, a child likely demonstrates the first-order ToM ability by the age of 5 (as measured by the Sally and Anne Task). However, they may struggle to inhibit (suppress) self-state belief (their knowledge of the reality), fail ToM tasks which require thinking from another character's perspective and continue to develop mature second-order false belief understanding (Jack thinks that I would like his gift, but I would not) that align with social and language maturity.

Second-Order and Higher-Order ToM Tasks

Second-order ability, on the other hand, infers what someone thinks about another person's mental state (Wimmer & Perner, 1983). Unlike first-order ToM abilities, second and higher-order tasks are associated with ascribing "nested" mental states and understanding a person's belief about someone else's mental state (participant infers if Sara thinks that Lisa dislikes her) (Bosco, Gabbatore, Tirassa, & Testa, 2016; Wimmer & Perner, 1983). Studies have repeatedly shown that the performance on the second-order tasks is more challenging than the first-order tasks (e.g., Mazza et al., 2001; Wellman & Liu, 2004). Performance on these tasks centers around the understanding of non-literal meaning, irony, and detection of humor (e.g., Happé, 1994). Furthermore, some studies (Kinderman, Dunbar, & Bentall, 1998; Liddle & Nettle, 2006; Stiller & Dunbar, 2007) have assessed participants on more demanding ToM tasks that involve third order (e.g., the manager believed that John knew that he expected him to work that day), fourth order and beyond (e.g., Sara hoped that Anne would believe her that she didn't know what Mike was planning to do). Such tasks involve reading or listening to narratives and inferring what one character thinks another person is thinking, what another person is thinking about the thinking or another person, and beyond.

ToM and Language-Based Cognitive Processes

Perceptual and cognitive processes are paramount in people's ability to infer complex emotional and mental states. Face recognition, for instance, is a significant factor in predicting ToM ability (Hildebrandt et al., 2015). However, with increased cognitive capacity, socialization, and repeated experiences, a child is expected to develop an understanding of sarcasm and white lies through adolescence (Miller, 2009), and exhibit mentalizing maturity beyond emotional recognition. These maturational processes are also correlated with neuroimaging studies that highlight longitudinal changes in cerebral activity during the performance of ToM tasks (Blakemore, 2008, 2012). These studies suggest that ToM is not a unitary construct, and this complex ability should be appreciated as a developmental context-driven process.

The child's command of language exhibits a strong relationship with knowledge about mental states during the developmental stages (Cutting & Dunn, 1999; Hildebrandt et al., 2015; Milligan et al., 2007). According to Piaget (1929), a child's ability to verbalize is paramount to the ToM ability. Through language, they verbalize their and others' feelings, intentions, and beliefs. It is not until age four when a child starts speaking coherently that they can demonstrates ToM by employing terms relevant to the concepts of think, feel, know and desire (Bartsch & Wellman, 1995; Parker & Gelletly, 1997). This relationship continues to exist in adulthood, which helps adults to explicitly represent reasoning and understanding of the mental states of others (Barrett et al., 2007; Lupyan & Clark, 2015; Newton & de Villiers, 2007; Peterson & Miller, 2012; Pyers & Senghas, 2009).

Within the context of ToM, our language and communication help internalize multiple perspectives and represent other mental states, which is an integral part of social interactions (Fernyhough, 2008). Early in development, language, with the help of internalized words, gestures and cues, likely facilitates and scaffolds a child's ability to control thoughts and behaviors of self and others (Meins & Fernyhough, 2015). From this standpoint, language facilitates the verbal representation of thoughts, reasoning, and mental states significant for ToM. It enables verbal self-monitoring and self-regulatory abilities that represents executive control capacity (Müller, Jacques, Brocki, & Zelazo, 2009).

Only a few studies have used narrative production tasks to investigate communication abilities in children diagnosed with developmental disorders and typically developing children (e.g., Diehl, Bennetto, & Young, 2006; Miniscalco, Hagberg, Kadesjö, Westerlund, & Gillberg, 2007; Tager-Flusberg, 1995). In contrast to parental reports, narratives provide a direct measure of social cognitive and pragmatic abilities that are more comparable to children's daily social cognitive development (Luo & Timler, 2008). Parental questionnaires and self-reports limit the opportunity to retrieve comprehensive information that can be gathered from narrative measures.

Most second-order ToM tasks rely on language abilities to comprehend the vignettes and “read between the lines” of what is being inferred. Narrative techniques are well suited to investigate the social cognitive mechanisms and identify perceptual integration and social thinking in a social context (Annotti & Teglasi, 2017). One such measure, the Strange Stories task (Happé, 1994) consists of short stories that ask participants to explain the thinking behind a character’s behavior. The stories require understanding of jokes, bluff, sarcasm, and scenarios where character’s behaviors contradict their intentions. Additionally, Faux Pas (Baron-Cohen, O’Riordan, Stone, Jones, & Plaisted, 1999) is also comprised of vignettes depicting impolite and socially inappropriate remarks from one character towards another. This task requires participants to detect if something shouldn’t have been said in that situation, what was said, and recognition that false belief caused a faux pas in a given situation.

Compared to narrative comprehension task that may restrict a participant from exhibiting ToM complexity beyond the provided vignettes, the narrative production task (discussed later) presents an opportunity to investigate several aspects of communication from language and structural components such as lexical and syntactic complexity to pragmatic facets and association between characters (Botting, 2002; Norbury & Bishop, 2003; Tager-Flusberg & Sullivan, 1995). High language demands do not drive the association between language and ToM (or EF). However, language abilities are the cognitive capacity that mediates the verbal execution of ToM skills. Unquestionably, domain-general cognitive abilities are likely recruited in the integration and representation of mature ToM abilities, which also explains the neural overlap between EF abilities and mature ToM processes (Binder et al., 1997; Perner & Aichhorn, 2008).

ToM Tasks for Adults

There are very few measures specifically developed to investigate ToM abilities among adults. False belief tasks (Baron-Cohen et al., 1985) have been modified to be used with adults in several studies (e.g., Aichhorn et al., 2009; Rothmayr et al., 2011; Saxe & Powell, 2006; Schurz et al., 2013; Sommer et al., 2018; Van Overwalle, 2009; van der Meer et al., 2011). The construct of cognitive empathy is also used interchangeably with the construct of ToM. Several self-report measures, for example, Toronto Empathy Questionnaire (TEQ; Spreng et al., 2009), Interpersonal Reactivity Index (IRI; Davis, 1980, 1983b), and the Empathic Experience Scale (EES; Innamorati et al., 2019) are utilized to assess social interpersonal understanding. The self-report rating scale Interpersonal Reactivity Index (IRI; Davis, 1980, 1983b), for instance, which is primarily designed to assess cognitive and emotional aspects of empathy, is frequently used to assess ToM (e.g., Dodell-Feder et al., 2013; Moriguchi et al., 2006).

Another task, Reading the Mind in the Eyes task (RME; Baron-Cohen et al., 2001a), designed to assess ToM in children with Asperger Syndrome, requires participants to name the emotion of the person in the picture. Although several studies have utilized RME among healthy adults, the findings were heterogeneous for psychometric properties, yielding low internal consistency (Harkness et al., 2010; Olderbak et al., 2015; Voracek & Dressler, 2006) to acceptable psychometric soundness (Vellante et al., 2013). Moreover, similar to false belief tasks, RME also captures only a single ToM related domain of emotion recognition through eye images and lacks ToM complexity, given the sophisticated nature of this construct.

Likewise, these tasks only assess first-order beliefs. These measures (see Appendix A) either use the modified versions of children's ToM abilities or they investigate different albeit similar social cognitive abilities such as empathy, meta-cognition (Semerari et al., 2003), or self-reflection (Fonagy et al., 1991). Meta-cognition is defined as thinking about one's own interpersonal, cognitive, and behavioral dimensions, including perceptions and motivation (Flavell, 1979).

Semerari et al. (2003) initially developed a self-report rating scale, Metacognition Assessment Scale (MAS), to evaluate metacognitive functioning in psychotherapy. MAS then became the precursor for designing a Metacognition Assessment Interview (MAI; Semerari et al. 2012). MAI is a semi-structured interview that measures "self-domain," the ability to be aware of and monitor mental states and behaviors within oneself, and "other-domain," the ability to be aware of and adopt the perspective of another individual, and differentiate mental representations (Semerari et al. 2012). However, ToM has a more complex nature, since it not only encompasses first-order processes but second order abilities, attributing mental states about self, other, and other's mental states about someone else (Bosco et al., 2016; Nichols & Stich, 2003).

Similarly, self-reflection captures the capacity to recognize thoughts, feelings, beliefs, and desires in oneself and others (Fonagy et al., 1998). Grounded on the conceptualization of self-reflection, Reflective Functioning Scale (RFS; Fonagy et al., 1998) assesses an individual's ability to mentalize attachment relationships. It is coded from the transcripts of the Adult Attachment Interview (AAI; Taubner et al., 2013). Trained coders rate the responses on an 11-point scale to provide a global score. Although ToM and self-reflection are related to metacognitive constructs, a study conducted by Taylor et al. (2008) in a clinical ASD sample did not find a significant association between ToM as assessed by Strange Stories and RME task and self-reflection as assessed through RFS (Taylor et al., 2008). RFS scoring has also been applied to clinical interviews such as Brief Reflective Functioning Interview (BRFI; Rudden et al., 2005) and the Reflective Functioning Rating Scale (RFRS; Meehan et al., 2009). However, these measures are more suitable for clinical than normal community samples (Katznelson, 2014). Moreover, a global score underestimates the complexity of mentalizing abilities (Choi-Kain & Gunderson, 2008; Gullestad & Wilberg, 2011). Several studies have adopted the approach of accumulating the ToM score across tasks (e.g., Fahie & Symons 2003; Saltzman et al. 2000; Yirmiya et al., 1998). Given the diversity of ToM measures and the different abilities that they measure, combining these scores may not provide any useful information, especially if a study intends to explore ToM.

To capture the complexity of ToM, other researchers have designed more sophisticated tasks that capture the second-order mental abilities such as the Strange Stories task (Happé, 1994) and Faux Pas (Baron-Cohen et al., 1999). The Strange Stories task (Happé, 1994), for example, assesses the understanding of complex mental states such as misunderstanding, and double meaning statements in the context of presented social scenarios. Strange Stories task has been used extensively with children, both in typical and (e.g., Devine & Hughes, 2013) and clinical samples (e.g., Charman et al., 2007; Kaland et al., 2002; Velloso et al., 2013), and healthy adolescents and adults, and with ASD (Jolliffe & Baron-Cohen, 1999; Kaland et al., 2005).

Although the tasks mentioned above acknowledge a developmental course of ToM maturity, yet they fail to capture its complex dynamic nature. For example, False Belief tasks were designed for children, but they are frequently modified for studies in adults. Similar first-order and second-order perspective-taking tasks (e.g., Faux Pas) sample narrow behaviors and rely extensively on narrative comprehension abilities. Moreover, methodological differences and vague operationalization refer to explicitly or implicitly different performance expectations (Annotti & Teglasi, 2017). ToM abilities, on the other hand, rely on situational factors, and on the bidirectional interplay between participants.

Popular ToM Measures and Their Limitations

The most convenient method to measure social cognitive processes in adults is through self-report measures, asking them directly how they feel in social situations, and comparing their responses to a predetermined response set. A significant criticism regarding the use of self-report measures has been the aspect of social desirability (e.g., Eisenberg & Fabes, 1990; Eisenberg & Lennon, 1983), and the assumption that participants report tendencies that may fit well with their desired behavior rather than their actual disposition (Eisenberg, Fabes, Bustamante, & Mathy, 1987). More specifically, self-report measures lack the sophistication to adequately sample situational and relational processes that evolve between two individuals over the progression of an interaction.

As explained earlier, ToM consists of a constellation of domains that include an individual's capacity to attribute mental states, emotions, desires, intentions, and beliefs, use this knowledge to explain behavior, and modify/update their future actions. Empirical studies have relied heavily on perception, attribution biases, self, and social schema, impression formation, and the like (Baldwin, 1992). Carpendale and Lewis (2006) asserted that regarding the theory of mind, literature has stressed exploring cognitive mechanisms more than perspective-taking abilities and social-relational processes. Similarly, some of the tasks used in experimental studies (as highlighted above) seldom present situational diversity and interactional dynamics that unfold during communication. Given the limited emphasis on a process-oriented approach in assessing ToM, most popularly used tasks lack ecological validity (Jenkins, Siefert, & Weber, 2020; Mar, 2018).

As highlighted in earlier sections, most studies rely on a single measure of ToM, using either False Belief task, Strange Stories Task, or RME task to assess their social cognitive processes. ToM abilities are context-dependent and dynamic in nature and can very well be explored using a narrative technique. A few studies have used narratives to investigate communication abilities in children diagnosed with developmental disorders and typically developing children (e.g., Diehl, Bennetto, & Young, 2006; Miniscalco, Hagberg, Kadesjö, Westerlund, & Gillberg, 2007; Tager-Flusberg, 1995). Parental questionnaires and self-reports limit the opportunity to retrieve comprehensive information that can be gathered from narrative measures. Moreover, several studies have concluded that children and the clinical population struggle to perform second-order tasks and find them difficult over first-order tasks (Mazza et al., 2001; Wellman & Liu, 2004). However, other studies (e.g., Jones et al., 2010; Liddle & Nettle, 2006; Slaughter & Repacholi, 2003) have indicated that on some tasks, individuals with ASD and conduct difficulties can score very close to ceiling, and likely benefit from higher order ToM tasks.

In contrast to the above-mentioned measures, narratives provide a direct measure of social cognitive and pragmatic abilities that are more comparable to children's daily social cognitive development (Luo & Timler, 2008). The narrative task presents an opportunity to investigate several aspects of communication from language and structural components such as lexical and syntactic complexity to pragmatic facets and association between characters (Botting, 2002; Norbury & Bishop, 2003; Tager- Flusberg & Sullivan, 1995).

Narratives and Neural Correlates

A comprehensive review provided by Mar (2004, 2011) identified an association between the narrative tasks and activations in the frontal and temporal regions of the brain. Like other critics, Mar (2011) highlighted extensive support for the social information processing activation mechanism by using only the false belief task paradigm or first-order ToM tasks. In his extensive meta-analysis, Mar (2011) identified the brain regions implemented in the story-based tasks to explore the theory of mind (false belief stories, social violations stories, sentences, ToM stories comprehension). The regions most likely to be activated during these tasks included mPFC, frontal pole, ACC, mSFG, angular gyrus regions that included pSTS/TPJ, pSTG, pMTG, MTG; STS, a MTS, and SFG. These clusters were located in the right angular gyrus regions, including the pSTS, TPJ, and pSTG. Left region areas also showed activity but with slightly lower likelihood. Left temporal pole and left amygdala along with SFG were also mentioned in some studies but less frequently. Performance on the story-based tasks activated rTPJ followed by the mPFC. The author also identified the brain region activation in the non-story-based task and highlighted that contrary to story-based tasks, non-story-based tasks showed the most activation in the mPFC followed by rTPJ. These differences and lack of consensus regarding the brain regions associated with ToM can likely be associated with differences in methodological approaches to investigate this construct.

Narrative comprehension is used more frequently in the empirical literature than narrative production (Mar, 2004). There are very few studies that have explored neural correlates implicated in narrative production. Braun, Guillemin, Hosey, and Varga (2001) in their study with English and American sign language proficient participants subtracted areas of motor movement during the narrative production and identified that medial and superior frontal gyri, bilateral middle temporal gyrus and superior temporal gyri and sulcus, posterior cingulate and other parietal regions were activated during the narrative production. Another study (see Braun et al., 2001) instructed participants to imagine emotional and non-emotional plans. The investigators found that the mental stimulation of emotional plan activated left and right medial frontal gyri, left anterior cingulate, bilateral posterior, bilateral anterior and right posterior middle temporal gyrus, and inferior temporal gyrus. These studies have provided convergent findings and have identified brain regions implemented for both, narrative comprehension and narrative production. The brain region involved in narrative production and comprehension involve medial and dorsolateral frontal cortex regions, temporal regions, including the temporoparietal junction, and the posterior cingulate (Mar, 2004). However, this area lacks confirmatory findings and requires empirical support.

Narratives and EF Abilities

To this date, very few studies have utilized storytelling tasks to explore the association between social cognitive processes and EF. A study utilized TAT stories (Murray, 1943 cards 2, 5, and 14) as a measure of EF in a sample of closed head injury (CHI) patients (Phillips-Bui, 2000). The author identified that CHI patients demonstrated a significant difficulty in completing stories coherently. Moreover, the performance on the storytelling task was positively correlated (r = .68) with a task of cognitive flexibility and motor speed (DKEFS design fluency task; Jones-Gotman, 1991) and a task of executive functioning and decision making ($r = .45$; Tinker Toy Test; Lezak, 1995, p.659) but not significantly correlated with a verbal fluency task (COWA; Benton & Hamsher, 1976), which is a timed task, and relies on speeded word generation.

Although the lack of association between TAT narratives and a verbal fluency task would be counter-intuitive, it is worth highlighting that the storytelling task is a thoughtful, deliberate process. On the contrary, verbal fluency is a speeded task and leaves less room for conceptualization and deliberation. The situational and relational dynamic complexity that unfolds between at least two individuals cannot be disregarded. In an interaction, two individuals may simultaneously acknowledge their thought processes, attempt to suppress them (successfully or unsuccessfully) and attempt to predict each other's perspectives. Communication and feedback exchanged between two or more persons have the potential to influence and modify their social cognitive processes. Without contextual interactions, comprehending social cognitions is confined to an observer's isolated and distinct view, which may result in erroneous conclusions about interpersonal relationships and associated mentalizing processes.

TAT Narratives as Social Information Processing Samples

Story-based narrative measures can provide an opportunity to investigate socially and situationally relevant mentalizing abilities (Jenkins, 2017; Mar, 2018). The Thematic Apperception Test (TAT) is a narrative assessment tool initially designed to assess personality, interpersonal and intra-personal dimensions (Morgan & Murray, 1935; Murray, 1943). TAT is a unique instrument since it draws on internal social and interpersonal processes to construct characters and representations of interpersonal interactions elicited by looking at images of interpersonal situations (Cramer, 1999). Several scoring systems have been created to produce consistency in scoring and increase inter-rater reliability (Atkinson et al., 1954; Cramer, 2006; Jenkins, 2008; Smith et al., 1992). Stein and Slavin-Mulford (2018; Stein et al., 2012), for example, scored TAT narratives by developing the Social Cognition and Object Relations Scale-Global (SCORS-G). Similarly, Feffer (1959, 1967, 1970; Leeper, Dobbs & Jenkins, 2008) developed Interpersonal Decentering with theoretical foundations based in Piaget's (1972) conceptualization of egocentrism and perspective-taking. Although these systems are most often scored from narratives elicited by TAT or Picture Story Exercise (PSE; O'Gorman et al., 2020; Schultheiss, Liening, & Schad, 2008), they can also be scored from other narratives such as expressive writing essays (Jenkins, Austin, & Boals, 2013; Jenkins, Shamji, Straup & Boals, 2022), early memories (Pinsker-Aspen, Stein, & Hilsenroth, 2007) or clinical interviews (Inslegers et al., 2012).

Studies comparing participants with ASD and neurotypical controls have successfully utilized TAT for capturing nuanced social cognitive processes not usually assessed through first or second-order ToM measures (e.g., Beaumont & Newcombe, 2006; Eurelings-Bontekoe et al., 2011). Narrative measures are successfully utilized in clinical populations. Beaumont and Newcombe (2006) utilized TAT to compare 20 patients with high functioning autism with 20 control participants. The authors compared the coherence of narratives regarding mental state words, utilization of causal mental statements, and action causal statements. Their analysis indicated that individuals with high functioning autism used fewer mental state causal statements than controls. Although high functioning autism patients did not differ proportionally on the use of mental state words compared to their controls, they were less likely to explain their characters' mental states. In a different study, Eurelings-Bontekoe et al. (2011) assessed 27 patients diagnosed with ASD between the ages 19 and 54 (M = 30.6, SD = 9.71) and scored their TAT narratives on SCORS (Westen, 1985, 1991a, 1991b) system. Their analysis indicated that ASD patients had significantly lower scores on Emotional Investment in Relationships and Moral Standards (EIRM) and Understanding of Social Causality (SOC) and exhibited lower social-emotional insight than other psychiatric patients in their sample. Their results indicated that social causality was negatively correlated with central coherence (r = -.32), theory of mind (r = -.48), and social connectedness (r = -.34) in patients with ASD. Empirical studies have found that narrative measures are more sensitive for picking up social cognitive nuances than False Belief and other related tasks used to assess ToM in adults (Jones et al., 2010; Liddle & Nettle, 2006; Slaughter & Repacholi, 2003).

Various related constructs and theories have been put forth to understand and explain interpersonal processes related to the phenomenon of decentering. These constructs include taking the role of the other (Mead, 1934), perspective-taking (Piaget, 1972), role-taking (Enright & Lapsley, 1980), cognitive empathy (Farrant, Devine, Maybery, & Fletcher, 2012), and Interpersonal Decentering (Feffer, 1959; Feffer & Jahelka, 1968).

Decentering may well be explained in terms of Piaget’s theory of cognitive development, the concrete operational stage. From 7 to 12, a child develops ability to think critically and from multiple perspectives. A child under the age of 7 cannot grasp how a three-dimensional representation of three mountains would be interpreted by someone else (Piaget & Inhelder, 1956; Surtees & Apperly, 2012). Elkind (1967) defined the inability to distinguish between subjective schemas and experiences and objective reality as “egocentrism” (Artar, 2007). Decentering occurs once children can separate their own ideas and emotions from those of others (Piaget, 1972). The capacity to consider from different viewpoints occurs when a child can combine their own ideas and emotions with others’ views before acting on them, which then remains available as a capacity of cognitive maturation (Feffer, 1970). Feffer (1970) extended Piaget’s work on cognitive development by applying decentering to the structure of social concepts and relationships.

Interpersonal Decentering, as explained by Feffer, is how people can recognize different aspects of social situations and adapt their behaviors and actions accordingly (Feffer, 1967). Every individual’s ability to reflect on his or her behavior from more than one perspective is a useful tool for social interactions (Feffer & Suchotliff, 1966). Feffer defined decentering as a role-taking perspective and the ability to see and understand the world from another person's perspective. The ability to take the perspective of another individual in a situation requires not only explicitly verbalizing thoughts, but also a pragmatic approach to think and act accordingly in a particular circumstance. In their study of Interpersonal Decentering and interpersonal problems, Jenkins et al. (2021) referred to Interpersonal Decentering scores as person-situation interactions to establish its construct validity. In their argument, the authors asserted that when a concept is theorized to change across contexts, the measures of processes such as decentering do not need to demonstrate internal (cross-situational) consistency as a condition for validity (Atkinson, 1981; Cramer, 2017; Jenkins, 2017; McClelland, 1980). Studies of causal validity may be conducted if the theory identifies settings (image stimuli) that can be used as realistic experimental manipulations to elicit the expected score differences (Bornstein, 2011; Borsboom et al., 2004).

In this regard, Interpersonal Decentering is the process of recognizing distinct features of social circumstances and adapting one's behavior and actions accordingly (Feffer, 1967). The capacity to reflect on one's behaviors and actions from several angles is a social maturation skill (Feffer & Suchotliff, 1966). It is defined as the capacity to view and comprehend the world through the perspective of another person. Taking a person's viewpoint in a situation may not need verbalizing reasons and intents, but rather a pragmatic way to think and behave appropriately. Although this ability typically develops in early developmental years and continues to mature, the level to which an adult employs this mentalization varies (Jenkins, Dobbs & Leeper, 2015).

It is noteworthy that neurotypical adults possess ToM abilities. However, they differ in mentalizing activation processes. Jenkins, Siefert, and Weber (2020) argued that Interpersonal Decentering represents situationally activated interpersonal information processing. Mature interpersonal decentering ability is a complex process since the individual decenters from the self-perspective, engages in understanding another's perspectives, and reflects on one's own situationally specific belief. These processes cannot be replicated through predetermined tasks but are recreated by the individual using the specific situations presented in story-making narrative tasks. Additionally, studies in cognitive neuroscience have also supported narrative assessment methods as a dynamic mentalizing process-oriented activation method (Mar, 2011, 2018).

Present Study

ToM and EF depend on distinct yet shared neural circuits in the mPFC, IPL, TJP, and IFG. Moreover, behavioral measures of EF and ToM overlap significantly, particularly in childhood. Although ToM and EF may appear partially separable in the brain as provided by neuroimaging studies, they also demonstrate commonality of brain regions and functional faculties. Additionally, brain development studies show that both ToM and EF develop and mature during the initial five years of life. These accounts might explain the overlap and correlation between ToM and EF in various studies.

Although substantial research has been carried out to explore ToM, the generalizability of these studies is problematic for several reasons that include: (1) loosely defined ToM constructs (2) tasks used in the study designs have questionable validity (3) age-appropriateness and cognitive maturity level of participants are not always considered (4) some measures reach a ceiling effect in adults, and (5) ecological validity of these measures, which is the generalizability of performance to a real-life situation, is poorly addressed. Similarly, studies that have researched the EF and ToM association usually fail to specify the modality of task performance and the tasks' relevance and comparability with each other. For example, stories being read to the client likely pair well with an auditory rather than a visual inhibition task.

The purpose of our study was to explore the extent to which mentalizing abilities rely on various domain-general EF abilities, as highlighted by previous researchers (e.g., Ahmed & Miller, 2011; Brent, Rios, Happé, & Charman, 2004; German & Hehman, 2006). This study sought to examine EF's variance of attention, inhibition, working memory, and cognitive flexibility in explaining ToM performance on multiple ToM tasks. Currently, there has been no study that has explored the similarities and differences between performance on the mentalizing tasks and TAT narrative task generated by the participants and their associations with executive functioning.

As previously stated, deficits in ToM abilities are indicated in diverse clinical samples (Baron-Cohen et al., 2001b; Bora et al., 2005; Happé, 1994; Kerr et al., 2003). The findings from the current study can help researchers and clinicians select, utilize, and interpret appropriate ToM tasks while assessing general and clinical populations in the context of relevant EF and general cognitive dysregulations. By identifying the association between EF and ToM abilities, we can target fundamental cognitive skills treatments to support development in children and modify behavioral techniques in the rehabilitation settings for various neurological and developmental conditions. We intend to contribute to the overarching research on ToM by explaining the underlying factors contributing to successful ToM ability. By exploring these relationships among adults, I attempt to provide insight regarding the significance of EF abilities in activating and maintaining of ToM skills among adults, when both abilities are expected to be fully developed (Ahmed & Miller, 2011; Anderson, Levein, & Jacobs, 2002; Apperly, Samson, & Humphreys, 2009).

Research Aims and Hypotheses

There were two objectives of our study: 1) to evaluate the relationship between EF and ToM. I intend to investigate which EF abilities play a significant role across various ToM measures. 2) to assess whether participants in our sample show variability in ToM maturity, especially on higher-order perspective-taking tasks in the presence of intact performance on the EF measures. Substantial evidence for the contribution of EF abilities to social reasoning skills exists. Several studies have established that ToM development is significantly correlated with numerous domain-general functioning tasks, including inhibitory control (Flynn, O'Malley, & Wood, 2004; Ozonof et al., 1991) and mental set shifting (Frye et al., 1995). By assessing the performance on different ToM reasoning tasks, I intend to examine how the same domain-general EF abilities differentially explain the variability in social reasoning task performance. The specific questions that will be addressed by this study are:

Question 1: To what extent do working memory and cognitive flexibility predict performance on a False Belief task after controlling for attention and inhibition?

Question 2: To what extent do working memory and cognitive flexibility predict performance on Strange Stories after controlling for attention and inhibition?

Question 3: To what extent do working memory and cognitive flexibility predict performance on TOMI-SR after controlling for attention and inhibition?

Question 4: To what extent do working memory and cognitive flexibility predict performance on Interpersonal Decentering after controlling for attention and inhibition?

Although ToM is believed to be a unitary construct, varying tasks and measures designed to assess this social-cognitive understanding posit different, and incremental, executive and cognitive control demands (Bull et al., 2008). For instance, Lough et al. 's (2006) analysis indicated a significant overlap between the ToM story task and EF, but the relationship was not significant for the ToM cartoon task. The present study examined participants' ToM abilities and self-perceptions using a first-order false belief task, the Strange Stories task typically used in the studies of second-order ToM abilities, and a self-report ToM measure. Moreover, I expanded on the existing ToM literature by incorporating TAT narratives using the Interpersonal Decentering scoring system. The differential patterns of performance would provide insight regarding the contribution of specific EF abilities required for ToM task performance, especially on the narrative comprehension task as measured through the Strange Stories task and the narrative production task using Interpersonal Decentering maturity. To the best of my knowledge, there has been no study that has utilized the Interpersonal Decentering scoring scheme to assess the relationship between ToM and EF abilities in adults.

While the relationship between EF abilities and performance on ToM has been well documented, it has not been successfully identified as to which EF ability(s) significantly explain the performance variability across different perspective-taking tasks. Moreover, according to Ahmed and Miller (2011), since ToM abilities and tasks rely on separable parts, it is likely that some features of ToM are more taxing on EF abilities than the others. Finally, it is probable to assume that some aspects of EF may serve as an underlying component in performing ToM tasks while other EF abilities likely facilitate mature performance on ToM (e.g., Bull et al., 2008; German & Hehman, 2006). For example, although all tasks involve some aspect of attention, they may not require cognitive flexibility. For instance, some studies have used complex EF tasks such as the Wisconsin Card Sort Test (WCST) which measures abstract reasoning, set shifting and cognitive flexibility to examine the relationship between ToM abilities and EF (e.g., Rowe, Bullock, Polkey, & Morris, 2001). Several executive control processes such as inhibition, attentional shift, working memory and visual recognition load on the WCST task (Landry & Al-Taie, 2016). I aim to precisely delineate the incremental nature of EF abilities in explaining ToM skills by separately administering tasks of attention, inhibition, working memory, and cognitive flexibility requiring selective attention and set shifting.

In summary, the following hypotheses were tested:

Hypothesis 1: Working memory and cognitive flexibility will each significantly predict performance on False Belief task while controlling for attention and inhibition.

Hypothesis 2: Working memory and cognitive flexibility will each significantly predict performance on Strange Stories while controlling for attention and inhibition.

Hypothesis 3: Working memory and cognitive flexibility will each significantly predict performance on TOMI-SR while controlling for attention and inhibition.

Hypothesis 4: Working memory and cognitive flexibility will each significantly predict performance on Interpersonal Decentering while controlling for attention and inhibition.

Additionally, exploratory analyses to assess the association between performance-based ToM tasks and response time for each EF task (inhibition, attention, working memory and cognitive flexibility) were performed using multiple regression analysis.

CHAPTER 2

METHODS

The purpose of this section is to explain the utility of using a mixed-methods approach to explore the association between ToM and EF abilities. Given the complexity of the ToM construct, I incorporated qualitative and quantitative data collection, data analysis, and data inferencing techniques. A qualitative approach is the method of choice when the purpose of the research is to explore the intricacies of a construct by relying on the perceptions of individuals regarding a given situation (Stake, 2010). This approach, coupled with quantitative methods, allows to explore the more in-depth understanding of the contribution of EF abilities in explaining ToM performance in young adults. The following section will cover study participants, data collection methods, procedure to conduct data collection, independent and dependent variables associated with measures and tasks, and the data analysis plan.

Participants

A priori power analysis for multiple linear regression using G*Power 3.1 (Faul et al., 2009) estimated the necessary sample size for a medium effect size to a power of 0.8 at $\alpha = .05$ was 85 (Cohen, 1992). Since four hierarchical regression analyses were conducted for the present study, hypotheses were tested using Bonferroni adjusted alpha levels of .01 with G*Power estimated sample size of 119 participants. Due to the unbalanced gender ratio among research participants in the available pool, we predicted more female participation. We also anticipated ethnic diversity given the student representation at UNT. The initial data consisted of a total of 123 participants. However, 13 participants were excluded from the data set by performing listwise deletion as they discontinued participation and skipped more than two measures along with demographic variables. There was no indication of data missingness in the final data as all the items were made forced-choice except for the mental health information in the demographic variables. The retained data consisted of a total of 110 participants. Table 1 outlines demographic and health characteristics for the present study.

Table 1

Descriptive Statistics for Demographic Variables

Variables		n	%
Assigned Birth Sex	Female	84	76.4
	Male	26	23.6
Gender Identity	Cisgender Woman	73	66.4
	Cisgender Man	25	22.7
	Non-binary	6	5.5
	Agender	3	2.7
	Genderqueer	2	1.8
	Transgender Man	1	0.9
Sexual Orientation	Heterosexual/Straight	67	60.9
	Bisexual	19	17.3
	Questioning/Unsure	8	7.3
	Queer	7	6.4
	Pansexual	3	2.7
	Gay	3	2.7
	Lesbian	1	0.9
	Asexual	2	1.8
Relationship Status	Single	68	61.8
	In a Committed Relationship	24	21.8
	Dating Someone	11	10.0
	Married	5	4.5
	Divorced	2	1.8
Ethnicity	European/White/Caucasian	38	34.5
	Asian/Asian American	19	17.3
	African/African American	18	16.4
	Latinx/Hispanic American	13	11.8
	Biracial	18	16.4
	Middle Eastern	3	2.7
	Native/Hawaiian/Pacific Islander	1	0.9

(table continues)

Variables		n	%
Religious Affiliation	Christian	36	32.7
	Agnostic	18	16.4
	Atheist	13	11.8
	Don't know	12	10.9
	Religious, Unaffiliated	11	10.0
	Catholic	7	6.4
	Secular, Unaffiliated	4	3.6
	Protestant	3	2.7
	Hindu	2	1.8
	Buddhist	2	1.8
	Muslim	1	0.9
	Jew	1	0.9
Completed Education	Some High School	1	0.9
	High School Diploma or GED	27	24.5
	Less than 2 Years of College	30	27.3
	2-4 Years of College	32	29.1
	4-Year College Degree	11	10.0
	Master's Degree	6	5.5
	Doctorate Degree	3	2.7
	Current Education		
	Freshman	35	31.8
	Sophomore	20	18.2
	Junior	18	16.4
	Senior	20	18.2
	Graduate Student	8	7.3
	Not a Student at Present	9	8.2
Mother's Education	Other: No information/ elementary/middle school	4	3.6
	Some High School	6	5.5
	High School Diploma or GED	16	14.5
	Less Than 2 Years of College	11	10.0
	2-4 Years of College	8	7.3
	4-year College Degree	40	36.4
	Master's Degree	22	20.0
	Doctorate Degree	3	2.7
Father's Education	Other: No information/elementary/middle school	8	7.3
	Some High School	9	8.2
	High School Diploma or GED	15	13.6

(table continues)

Variables		n	%
	Less Than 2 Years of College	9	8.2
	2-4 Years of College	12	10.9
	4-year College Degree	30	27.3
	Master's Degree	16	14.5
	Doctorate Degree	11	10.0
Employment Status	Not employed NOT looking for work	14	12.7
	Not employed looking for work	25	22.7
	Employed 1-20 hours per week	39	35.5
	Employed 21-39 hours per week	18	16.4
	Employed 40 or more hours per week	14	12.7
Socio-economic Status	Lower Class	9	8.2
	Upper Lower Class	9	8.2
	Lower Middle Class	42	38.2
	Upper Middle Class	43	39.1
	Upper Class	7	6.4
Number of Siblings	None (0)	9	8.2
	One (1)	40	36.4
	Two (2)	29	26.4
	Three (3)	22	20.4
	Four (4)	3	2.7
	Five (5) or More	7	6.4
Children	No	106	96.4
	Yes	4	3.6
Number of Children	One (1)	1	0.9
	Two (2)	2	1.8
	Three (3)	1	0.9
English Fluency	Monolingual, English	80	72.7
	Bilingual, English	30	27.3
Handedness	Right-Handed	100	90.9
	Left-Handed	5	4.5
	Ambidextrous	5	4.5
Prescription Glasses	Yes	72	65.5
	No	38	34.5
Seizures/Epilepsy Diagnosis	No	94	85.5
	Yes	16	14.5
Autism Spectrum Disorder	Diagnosed/Suspected	15	13.6
	Not Diagnosed or Suspected	95	86.4

(table continues)

<table>
<tr><th colspan="5">Variables</th><th>n</th><th>%</th></tr>
<tr><td rowspan="3">Attention Deficit Hyperactive Disorder</td><td colspan="4">Diagnosed</td><td>17</td><td>15.5</td></tr>
<tr><td colspan="4">Suspected</td><td>24</td><td>21.8</td></tr>
<tr><td colspan="4">Not Diagnosed or Suspected</td><td>69</td><td>62.7</td></tr>
<tr><td rowspan="2">Mental Health Diagnosis</td><td colspan="4">Yes</td><td>48</td><td>43.6</td></tr>
<tr><td colspan="4">No</td><td>62</td><td>56.4</td></tr>
<tr><td rowspan="2">Medication for Mental Health</td><td colspan="4">Yes</td><td>43</td><td>39.1</td></tr>
<tr><td colspan="4">No</td><td>67</td><td>60.9</td></tr>
<tr><td rowspan="5">History of Head Injury</td><td colspan="4">Yes</td><td>8</td><td>7.3</td></tr>
<tr><td colspan="4">Blackout 30 minutes or less (n = 8)</td><td>7</td><td>6.4</td></tr>
<tr><td colspan="4">Blackout More than 30 mins (n = 8)</td><td>1</td><td>0.9</td></tr>
<tr><td colspan="4">History of Hospitalization (n = 8)</td><td>5</td><td>4.5</td></tr>
<tr><td colspan="4">No</td><td>102</td><td>92.7</td></tr>
<tr><td rowspan="2">Age</td><td>M</td><td>SD</td><td>Range</td><td>Skewness</td><td colspan="2">Kurtosis</td></tr>
<tr><td>21.47</td><td>4.53</td><td>18-37</td><td>1.71</td><td colspan="2">2.23</td></tr>
</table>

The mean age of our study participants was 21. 47 (*SD* = 4.53; between 18 to 37 years of age). In total, 24% of participants (*n* = 26) identified their assigned sex at birth as male and 76% (*n* = 84) participants mentioned that their assigned birth sex was female. Approximately 66% (*n* = 73) of participants identified as cisgender women and 23% (*n* = 25) as cisgender men. Also 6% (*n* = 6) participants identified as nonbinary, 3% (*n* = 3) agender, 2% (*n* = 2) genderqueer, and 1% (*n* = 1) as transgender man. Since the number of participants in these groups was small, these groups were combined as 'self-defined gender identity.' A total of 61% (*n* = 67) participants identified their sexual orientation as heterosexual/straight and 17% (*n* = 19) identified as bisexual. A small number of participants identified their sexual orientation as questioning/unsure 7.3% (*n* = 8), queer 6.4% (*n* = 7), pansexual 2.7% (*n* = 3), gay 2.7% (*n* = 3), asexual 1.8% (*n* = 2), and lesbian 0.9% (*n* = 1) and hence they will be grouped as 'self-identified sexual orientation.' Approximately 61.8% (*n* = 68) participants were single, 21.8% (*n* = 24) in a committed relationship, 10% (*n* = 11) dating someone. There were five participants (4.5%) who were married and two (1.8%) were divorced.

A total of 34.5% (*n* = 38) participants were White/Caucasians, 17.3% (*n* = 19) Asian/Asian-American, 16.4% (*n* = 18) African/African American, 11.8% (*n* = 13) Latino-American/Hispanic, three participants (2.7%) identified as Middle Eastern and one participant (0.9%) as Native Hawaiian/Pacific Islander. About 16.4% (*n* = 18) participated selected more than one ethnic category and were labeled as multiracial, including Asian and European, Asian and Latinx, European and Latinx, African and Asian, Latinx and Native American, and African American and European.

Our sample consisted of 31.8% (*n* = 35) freshman, 18.2% (*n* = 20) sophomore, 16.4% (*n* = 18) junior, 18.2% (*n* = 20) senior, 7.3% (*n* = 8) graduate students, and 8.2% (*n* = 9) non-student participants. Socioeconomically, 8.2% participants (*n* = 9) considered themselves in the low class, 8.2% participants (*n* = 9) in the upper lower class, 38.2% participants (*n* = 42) in the lower middle class, 39.1 % participants (*n* = 43) in the upper middle class, and 6.4% participants (*n* = 7) in the upper class.

Participants also provided optional demographic information on several variables (see Table 1). Nearly 72.7% of participants (*n* =80) were monolingual English speakers, and 27.3% of participants (*n* = 30) were bilinguals who were reportedly fluent in English. Almost 90.0% participants (*n* = 100) were right-handed, 4.5% (*n* = 5) were left-handed, and 4.5% (*n* = 5) participants mentioned that they are ambidextrous. Approximately 14.5% (*n* = 16) reportedly experienced seizures at least once in their life. A total of 15 participants were either diagnosed or suspected of autism diagnosis. Seventeen participants (15.5%) were diagnosed with ADHD, and 24 participants (21.8%) suspected of ADHD diagnosis. Nearly 43.6% (*n* = 48) self-disclosed being diagnosed with a mental health condition, and 39.1% (*n* = 43) mentioned taking medications for mental health concerns. Additionally, 7.3% (*n* =8) reported a lifetime history of experiencing a head injury, out of which seven identified blacking out for 30 minutes or less, and only one mentioned blacking out for more than 30 minutes. All the comparative and descriptive analyses were conducted on the groups with at least 10% (*n* = 11) participation.

Measures

Demographic Variables

A demographic questionnaire asked for participants' handedness, first language, and vision, besides asking for their age, gender, ethnicity, disability status, sexual orientation, and religious background (see Table 1 for a comprehensive list of demographic variables).

Executive Function Tasks

Attention

The visual search paradigm has been used in several studies (Treisman, 1977; Treisman & Gelade, 1980; Wolfe, 1998a) to study selective attention. Our research utilized a modified version of Motter & Simoni's (2008) task. Participants are asked to select a target response among distractor stimuli. The task used in our study requires participants to respond to the letter 'T' when presented in orange color and the upright position. Participants responded by pressing the spacebar every time they see an upright orange T and do not do anything if upright T is not present in a given set of stimuli. The following instructions displayed on the screen: "In the following task, you are required to find an upright orange T amongst blue Ts and upside-down orange Ts. Again, all you need to do is find an orange T. If you see the orange T, press space. Ignore the upside-down orange T, as well as blue Ts. It is very important to respond as fast as you can. If there is no orange T, wait for the next trial and do nothing." A total of 50 sets of stimuli were displayed, each with either 5, 10, 15, or 20 items. Response accuracy and search time was recorded for every response provided by the participant. Participants' response speed and error rate was also recorded for the descriptive analysis. Studies have demonstrated that visual search tasks can be reliably used to assess attention and cognitive functioning (Eckstein, 2011; Utz et al., 2013). Van Wert, Nova, Horowitz, and Wolfe (2008) reported test-retest reliability of r = .76 on the T among Ls task.

The Visual Search task in our study was based on the conjunctive search paradigm. Conjunctive search is the process of searching for specified combinations of attributes in objects (in our case, looking for an upright orange T amid blue and upside-down orange Ts). Although traditionally, a slope of reaction time and set size is created to measure search efficacy (Wolf, 1998a), we only utilized the weighted average for the reaction time (RT) with 5, 10, 15, and 20 distractors combined. This decision was made for two reasons: first, McElree and Carrasco (1999) did not find the main effect of set size on the search processing speed when they utilized the reaction time task instead of the standard mean RT patterns plotted for varying number of distractors. Secondly, we were less interested in the implicit processing dynamics of the search than its unique variance in explaining ToM performance.

Inhibition

Go/No-Go paradigm (Donders, 1969) tasks are used to measure inhibition and cognitive control in research participants. This study used the modified version of the Wessel (2017) task. The participants were asked to respond as soon as they see a target stimulus, but pause when they see a stop signal. Hence, participants are expected to react to stimuli as fast as they can.

Conversely, the stop-signal paradigm posits that once an action has been initiated, it is hard to stop behaviorally upon receiving the no-go signal. The following instructions were provided: “In the following trials, only press the space bar if you see the message “GO press the space bar” in green and do nothing if you see “NOGO press nothing” in red. Responses are noted for their speed and accuracy, and the proportion of commission errors is a measure of inhibition and cognitive control. According to Criaud and Boulinguez (2012), go/no-go task, when controlled for the proportion of go stimuli, no go stimuli, and the speed of stimuli presentation, "ensure a reliable probing of response inhibition mechanisms (also see Wessel, 2017)."

Working Memory

N-Back task (2 Back; Jaeggi, Buschkuehl, Perrig, & Meier, 2010). In this task, participants are presented with a sequence of stimuli (numbers, letters, etc.) one by one briefly on the screen. They are asked to select the target stimulus if it matches with the one presented *N* trials ago. For our study, we used 2 N; selection of the stimulus shown two trials ago. Letters were presented for 500 ms, followed by 2500 ms black period as used in Kane et al.'s (2007) study. The following instructions displayed on the screen: "In this task, you will see letters. Each letter is shown for a few seconds. You need to decide if you saw the same letter two letters ago. If you saw the same letter two letters ago, you press the "m" key. If you did it correctly, you will see the green color around the letter. If you press the button when you should not press it, you will see "red" around the letter." The responses were recorded for the number of correctly matched items, the number of missed items, and the number of false positives. Alternatively, percentages of correct matches, missed items, and false alarms were also obtained for descriptive analyses. The split-half reliability of the 2 Back task was reported to be 0.86 for the reaction time while the visual N back task was negatively correlated (r = -0.35) with the digit span forward (Jaeggi, Buschkuehl, Perrig, & Meier, 2010). Hockey and Geffen (2004) suggested that the test-retest reliability of working memory capacity in a spatial N-back paradigm varies from 0.49 to 0.86 depending on the value of N and whether the investigators have used accuracy of the reaction time or the number of correct responses for the analysis.

Cognitive Flexibility

Task switching (alternating-runs paradigm; Jersild, 1927; Rogers & Monsell, 1995). Task switching is an executive function task that consists of two simple categories and used them alternatively, such as color and shape, numbers and letters, etc. For this study, a number-letter task was used. The screen shows a 2x2 matrix, and paired characters appear in each quadrant. Participants are required to perform according to a pre-determined location cue. Each presentation shows a target character and a distractor character. Studies have demonstrated that the task switch cost persists with a large number of repeated trials (Stoet & Snyder, 2007).

Participants saw the following instructions on their screen: In the following task, you respond with button presses to letters and numbers. You will only need two keys (B and N). You will always see a letter/number combination, for example, G1. If the letter/number combination appears at the top of the screen, you need to respond to the letter. If the letter/number combination appears at the bottom of the screen, you need to respond to the numbers. Moreover, if you see a consonant on the top of the screen, press B if you see vowels, press N." The screen also showed images of the expected task and examples. Participants' reaction time (RT) in single-task block and task-switch trials was recorded. Task switch cost can be assessed by comparing single-task performance time with the pace at which they performed two tasks (number and letter) mixed. We obtained the accuracy and error total for single task and mixed task blocks. Miyake et al. (2000) calculated the reliability of the number-letter switching task by adjusting split-half (odd-even) correlations with the Spearman-Brown prophecy formula and found high reliability of r = .91.

Theory of Mind Tasks

False Belief

Saxe and Kanwisher (2003) devised a modified version of false belief stories task (Fletcher et al., 1995) to measure ToM. They designed 12 stories for each of the following categories for their MRI analysis: (1) false belief stories, (2) false photograph stories, (3) desires, (4) physical people, and (5) nonhuman descriptions. For this study, I used their 12 false belief task items, 12 desire items, and 12 physical description items. False belief items describe the character's action instigated by their belief, and desire stories describe the character's intentions. Physical description stories, on the other hand, ask questions from a physical perspective such as clothes, hair, facial marks, and so on.

Each story consists of a brief story with two associated comprehension questions (see Table 2 for sample items). The following instructions were provided: "Please read each story carefully. Along with each story, you will be given one fill-in-the-blanks question about the story. Underneath will be two words that could fill in the blank. Choose the correct word (to make the sentence true in the story) by pressing the left button to choose the left-hand word, and the right button to choose the right-hand word." After presenting each story, two-forced choice questions were displayed on the same screen to minimize reliance on memory. Each correct response is awarded '1' point, and an incorrect answer earns a '0.' False beliefs and desire story scores were combined to create a ToM task composite whereas physical description stories served as performance control. Participants could earn 0 to 12 points in each category. On similar tasks used for children, desire and intention task (Schult, 2002), the reported inter-rater reliability was between 83% to 90%. For the "not own desire task" (Wellman & Wolley, 1990), Hanson and Atance (2014) reported an agreement of Cohen's k = .81 between raters (Beaudoin et al., 2020). Similarly, on the change of object false belief paradigm (Hogrefe, Wimmer, & Perner, 1986; Perner, Leekam, & Wimmer, 1987), Behne, Liszkowski, Carpenter, and Tomasello (2012) reported a 100% agreement between raters. Change-in-location paradigm (Wimmer & Perner, 1983) Sally-Anne task, (Baron-Cohen, Leslie & Frith, 1985), reportedly had Cohen's *d* = 0.79-0.88 (Bialecka-Pikul et al., 2019).

Table 2

False Belief Story Categories and Sample Stories

Story Category	Sample Story	Fill-in-the-black statement with choices
False Belief	Anne made lasagna in the blue dish. After Anne left, Ian came home and ate the lasagna. Then he filled the blue dish with spaghetti and replaced it in the fridge.	Anne thinks the blue dish contains________ (a). lasagna (b). spaghetti
Desire	Benjamin wanted to get an A on the test. He canceled his plans for the weekend and planned to study. But he couldn't resist watching movies and didn't study. He got a B.	Benjamin wanted to get__________ An A (b). A B
Physical Description (People)	Jason is wearing blue jeans, white running shoes, a grey scarf, and a matching sweater. He has thick glasses on his long-hooked nose and a long blond beard on his chin.	The scarf Jason is wearing is______________ Blue (b). Grey

Note: Adapted from Saxe, R., & Kanwisher, N. (2003).

Strange Stories

Strange stories (Happé 1994; White, Hill, Happé, & Frith, 2009) is another ToM measure that tests subtle second order and higher order mentalizing abilities. The original task (Happé, 1994) consisted of 24 ToM stories and six control stories to comparably assess the understanding of physical states. This test assesses mentalizing processes such as double bluff, persuasion, white lies, and misunderstanding. White, Hill, Happé, and Frith (2009) proposed a modified set of Strange Stories. Each category consists of a brief story with an associated comprehension question (see Table 3 for sample items). The task contains original task animal stories (for children) and "natural physical state stories," along with "unlinked stories" to assess attention and memory for story facts. A comparable set of control stories asks participants about the physical aspects of the stories. Eight mental state stories and eight comparable physical state stories were used for this study.

Table 3

Strange Stories Categories and Sample Stories

Story Category	Sample Story	Associated Question	Scoring Scheme
Mental State	During the war, the Red army captures a member of the Blue army. They want him to tell them where his army's tanks are; they know they are either by the sea or in the mountains. They know that the prisoner will not want to tell them, he will want to save his army, and so he will certainly lie to them. The prisoner is very brave and very clever; he will not let them find his tanks. The tanks are really in the mountains. Now when the other side asks him where his tanks are, he says, "They are in the mountains."	Why did the prisoner say that?	**2 points**—reference to the fact that other army will not believe and hence look in other place, reference to prisoner's realization that that's what they'll do, or reference to double bluff **1 point**—a reference to an outcome (to save his army's tanks) or to mislead them **0 points**—reference to motivation that misses the point of double bluff (he was scared)
Human Physical Stories	A burglar is about to break into a jewelers' shop. He skillfully picks the lock on the shop door. Carefully he steps over the electronic detector beam. If he breaks this beam, it will set off the alarm. Quietly he opens the door of the storeroom and sees the gems glittering. As he reaches out, however, he steps on something soft. He hears a scream and something small and furry runs out past him, toward the shop door. Immediately the alarm sounds.	Q: Why did the alarm go off?	**2 points**—reference to animal which the burglar disturbed setting off the alarm by crossing beam (type of animal unimportant) **1 point**—reference to burglar setting off alarm (he was startled by the animal so crossed the beam); reference to animal setting off alarm without explaining it crossed the beam (he trod on a cat and it set off the alarm) **0 points**—reference to irrelevant or incorrect factors (the animal's screech set off the alarm); alternative reasons for alarm going off (a security camera saw him and set the alarm off)

Although previously participants read the stories and answered the questions after the story cards were taken away from them, my study presented the questions along with the vignettes on the same screen to minimize over-reliance on memory capacity, and for keeping story presentation consistent as the False Belief task. Provided responses were scored on a 0-2 scale where an incorrect response earned ‘0’, a score on ‘1’ for partially or implicitly correct answer, and a score of ‘2’ for the correct response. Participants could earn between 0 to 16 points on each category. The reported interrater reliability correlation coefficient for these stories was good at Cohen’s *d* = .89, respectively.

Self-Report Theory of Mind

Theory of Mind Inventory Self Report-Adult (ToMI: SR-Adult; Crehan, Althoff, Riehl, Prelock, & Hutchins, 2020; Hutchins, Lewis, Prelock, & Brien, 2021). This is a self-report measure for adults ages 18 and above with 8^{th} grade-level reading skills who are considered on a high functioning autism spectrum. There are 60 items on this measure. Each item taps advanced aspects of social cognition such as affective empathy, mixed emotion and emotion recognition, time perception, episodic memory, use of metaphor, social perception, double bluff, hypocrisy, social commonsense, stereotypical thinking, and the like. Items are in the form of statements. For example, “People do certain things when they are not interested in talking to us (e.g., they might look away for a long time or start fidgeting). I can recognize when a listener is not interested in what I am saying [Complex Social Judgement].” Participants are asked to read each statement and place a mark at the appropriate 20-unit continuum point ranging from ‘definitely not,’ ‘probably not,’ ‘undecided,’ ‘probably,’ and ‘definitely.’ Responses are then evaluated using a thematic analysis approach on a 0 to 20 continuum. Reportedly, the content validity of TOMI: SR-Adult was established from collaboration and suggested revisions from the experts in ASD.

The internal consistency reliability for TOMI: SR-Adult for the individuals with ASD and typical adults combined is .98, and typically developed adult was an alpha of .95, indicating a high degree of internal consistency. Cronbach's alpha was conducted to obtain the internal consistency for the TOMI-SR-Adult measure. The reliability analysis indicated a high degree of internal consistency ($\alpha = .94$) for this sample.

Interpersonal Decentering

The Thematic Apperception Test (TAT; Morgan & Murray, 1935; Murray, 1943) and Roberts Apperception Test for Children-2 (Roberts-2; Roberts & Gruber, 2005). The TAT and Roberts-2 are narrative assessment instruments used primarily in clinical and counseling settings to gather information about relationship conflicts, anxieties, underlying motives, concerns, and social perceptions. For our study, we used cards that depicted at least two characters, i.e., Cards 2, 4, and 13MF. Similar, we used Card RAT-2's Card 1. These cards were chosen because each card shows two characters in a situation that often elicits interactive stories. As a group, these pictures sample a range of affective states. These cards were presented on the screen for 20 seconds with the following instructions: You will see a series of pictures, and I would like you to make up stories about the people shown in the pictures. Tell whatever story comes to your mind about what is happening, who the people are, what they are feeling, thinking, and wanting. Tell what led to the situation shown, what they will do, and how everything will turn out in the end. Try to tell a whole story, with a beginning, middle, and end, about each picture (see Appendix G for comprehensive instructions). The provided TAT stories were then scored for nine levels of increasingly complex interpersonal decentering activity (Feffer et al., 2008). Discrete social interaction units in a story that involve at least two characters in the same place and time (perhaps one in the internal awareness of another) were identified, and each unit was scored for one of 9 levels of Interpersonal Decentering maturity (see Table 4). Scores range from 1 to 9, where 1 represents an undifferentiated implicit relation, and 9 represents the self in the interactive internalized state in relationship with others. Levels 1 to 4 are considered less mature levels of Decentering as these levels are concrete, undifferentiated, or sequential, and do not incorporate a mature abstract cognitive representation of another person.

Table 4

Scoring Categories for Interpersonal Decentering

Score	Description	Example
1	Undifferentiated relationship	"They didn't have food."
2	Non-reactive directional relationship	"Wife is helping him."
3	Reactive directional relationship	"Her mother got really upset when she told her that she is in love with Johnny."
4	Interactive directional relationship	"The man offered to buy her a drink, and she kindly said, "No thanks," but he insisted."
5	Internalized other, simple representation	"Her mother does not think much of Johnny."
6	Internalized other, surface characteristics	"The guy thought that she would never really leave him."
7	Internalized other, internalized state	"She didn't think that the guy understood the situation."
8	Internalized other's internalized other	"She is eagerly awaiting the day when her mother decides that Johnny is good enough."
9	Internalized self-other interaction	"She plans to sneak away in the dark of night and run away with him."

Note: Adapted from the scoring manual for Feffer's Interpersonal Decentering (Feffer et al., 2008, p. 152).

Scoring of 1 was given to the representation of characters in an interaction that is not differentiated from one another, for example, "They didn't have food." Characters in levels 2 to 4 are differentiated from each other when one character's action is directed towards the other character. At level 2 no response is provided by the other character ("Wife is helping him"), but one character's actions are directed towards other character. For level 3, a response is incorporated by the other character in the story ("Her mother got really upset when she told her that she is in love with Johnny"). Level 4 integrates an action-reaction sequence when a response is provided back to the initial action ("The man offered to buy her a drink and she kindly said "No thanks" but he insisted").

Levels 5 to 9 are more mature levels of Interpersonal Decentering as they require complex internalized states of characters by another (Feffer et al., 2008). Level 5 and 6 are identical regarding internalization except for the elaborated internalized state of the character involved in level 6. For example, "Her mother does not think much of Johnny" demonstrates internalization with the mother's evaluation of Johnny, which receives a score of 5. For the same scenario, "The guy thought that she would never really leave him" receives a score of 6, which is internalized other elaborated by surface characteristics (her not leaving). Level 7 incorporates the sophistication of internalizing another character's internal state, for example, "She didn't think that the guy understood the situation." For level 8, one character internalizes another character, who further internalizes a third character: "She is eagerly awaiting the day when her mother decides that Johnny is good enough." In the highest level, 9, "the characters reflect on their thoughts, feelings, or actions with another individual" (Feffer et al., 2008). For example, "She plans to sneak away in the dark of night and run away with him." The overall mean, "average interpersonal decentering maturity," was obtained for each participant across stories, which is less influenced by the participant's story response productivity. Moreover, the single highest "best effort" score was also obtained. (Jenkins et al., 2008b).

Jenkins (2008a, 2021) found that the Interpersonal Decentering scoring system has high content validity. The obtained inter-rater reliability for Interpersonal Decentering during training was *rho* >.80. Previous studies reported good inter-rater reliability, *rho* >.90 for similar analysis

(Jenkins & Nowlin, 2018). For the present study, Interpersonal Decentering was scored by a multicultural team of eight different scorers working in groups of three, each with a team leader, except for one story set told to Roberts-2 Card 3 (Black), which was scored by the two team leaders supervised by Dr. Sharon Rae Jenkins. Having achieved adequate reliability using the manual and practice materials, scorers determined their scores independently, then met as a team three times weekly to reconcile scoring discrepancies, achieve consensus, and determine scoring conventions and benchmarks, as described by Jenkins (2008b). Reliabilities were calculated by picture set using Spearman's *rho* since the scale is best treated as ordinal. Reliabilities for number of interaction units ranged from *rho* = .80 to .87 except for three low outliers (.63, .67, .76). Reliabilities for the per-set average averaged across sets ranged from *rho* = .72 to .83, again with three low outliers (.53, .65, .67). No two outliers came from the same story set. Supplementary scoring materials are available at the University of North Texas Scholarly Works Repository.

Procedure

Approval from the Institutional Review Board (IRB) was obtained from the University of North Texas, Denton. Upon receiving the approval, we recruited participants through an online recruitment system at UNT, known as SONA, and advertisements on social media platforms such as Facebook. UNT participants received extra credits towards a course and participants recruited from social media forums received an Amazon gift card worth $ 10. Due to the COVID-19 pandemic, the research study was listed with information such as the investigator's contact information, the title of the study, time commitment, and a sign-up time to schedule a zoom meeting via Qualtrics survey link. Questions on SONA specified open time availability, along with participation requirements such as stable internet connectivity, availability of a desktop computer or laptop, for the EF tasks, and quiet and private location for maintaining the integrity and validity of the assessment measures. Participants were emailed the zoom link on the agreed-upon time. Every session began with a brief overview of the study with the investigator to troubleshoot technical difficulties, and minimize premature study dropouts followed by a detailed overview of the informed consent, going over participation requirement such as internet connection, private and distraction free location, use of prescription glasses, pop-up blocker diagnosis, and other participants' questions. Investigator remained on the call for the entirety of the duration (90 to 120 minutes) with microphone and camera turned off to minimize distraction. Participants were permitted to take brief pauses between tasks as required. The data were gathered along with other measures.

False Belief task, Strange Stories task, narrative production task, and self-report measures were administered via Qualtrics. All EF performance-based tasks were administered via PsyToolkit, which is an online platform for running cognitive-psychological experiments (Stoet, 2017, 2010).

The tasks and measures were presented in the following order

1. TAT
2. Attention
3. Inhibition
4. Working Memory
5. Cognitive Flexibility
6. False Belief Task
7. Strange Stories
8. ToM Self-Report Measure
9. Demographics

10. ADHD, ASD, and other social cognition measures (not used for this study)

Data Analysis

To conduct statistical analyses, the collected data was transferred from the Qualtrics platform for the SONA study data collection to version 28 of the Statistical Product and Service Solutions (SPSS; IBM Corp., 2021) software program. The EF tasks from the psytoolkit were downloaded, and all the trials in each task were aggregated to obtain descriptive data for the accuracy, error rate, and reaction time. Before executing the hypothesis testing process, data was inspected for potential errors and completion. General screening guidelines as outlined by Tabachnick and Fidell (2007) were used to examine data for missing values, out of range errors, apparent anomalies before running descriptive.

The cutoff values for the response time for each performance task were identified to check for performance validity. Demographic and health history variables were coded, labeled for reference and clarity, and checked for the normalcy of data distribution. Further, univariate outliers, score distributions, and primary descriptives of the data were examined using graphs and frequency tables for assessing nonnormality of data points such as bimodality, skewness, and kurtosis of distribution.

CHAPTER 3

RESULTS

On the Visual Search task, 64.5 % (*n* = 71) obtained a maximum score of 30 (total trials = 30). Approximately 88% of participants scored higher than 28 on this task. Descriptive analysis (see Table 5) revealed non-normalcy of the Visual Search task, skewness = -4.26, kurtosis = 18.56. Hence, Visual Search accuracy scores were first reflected prior to performing log transformation. Reflection involved subtracting each value from a larger number than the maximum value (max + 1-variable). A log 10 transformation procedure was then utilized to reduce negative skewness (Munro, 2005).

Table 5

Descriptive Statistics for Executive Functioning Variables

Executive functioning Tasks	M	SD	Range	Skewness	Kurtosis
Visual Search Task (Attention)					
Visual Search Accuracy	29.07	2.50	15-30	-4.26	18.56
Visual Search Accuracy Transformed	1.16	0.27	1-2.20	2.17	5.11
Visual Search Accuracy RT (Ave.)	1.09	0.24	0.73-2.00	1.38	2.62
Visual Search Accuracy RT (WA)	1.09	.20	.74-1.75	.78	.53
Visual Search Accuracy RT (5 D)	0.82	.17	.51-1.35	.77	.55
Visual Search Accuracy RT (10 D)	.98	.19	.71-1.61	.88	.52
Visual Search Accuracy RT (15 D)	1.20	.24	.74-2.07	.91	1.15
Visual Search Accuracy RT (20 D)	1.37	.34	.84-2.38	1.02	.76
Visual Search Error	1.73	2.87	0-18	3.65	15.10
Visual Search Error RT	0.66	0.48	0-2.09	0.33	0.88
Go No-Go Task (Inhibition)					
Go No-Go Accuracy (Cumulative)	68.15	1.85	62-70	-1.28	1.46
Go Accuracy	49.94	0.31	48-50	-5.26	28.37
Go Accuracy RT	0.38	0.06	0.28-0.68	1.68	5.92
Go Error Count	0.06	0.31	0-2	5.26	28.37
Go Error RT	0.09	0.42	0.00-2.00	4.43	17.91
No-Go Accuracy[a]	18.21	1.79	12-20	-1.17	1.03

(table continues)

Executive functioning Tasks	M	SD	Range	Skewness	Kurtosis
No-Go Error	1.79	1.79	0-8	1.17	1.03
No-Go Error RT	0.25	0.22	0-0.28	2.38	12.17
2-Back Task (Working Memory)					
2-Back Cumulative Accuracy	85.66	8.61	61-99	-.64	0.12
2-Back cumulative Accuracy RT	2.42	0.16	2.06-2.82	-.17	-.20
2-Back cumulative Error	14.34	8.61	1-39	.64	.12
2-Back cumulative Error Time	1.98	0.65	.61-3	-.28	-.84
2-Back Match Accuracy	21.55	6.77	6-38	0.13	-0.42
2-Back Match Accuracy RT	0.66	0.15	0.33-1.35	1.19	3.56
2-Back Non-Match Accuracy [a]	64.12	7.19	40-79	-0.61	0.92
2-Back Non-Match Error	14.34	8.61	1-39	0.64	0.12
2-Back Non-Match Error RT	1.98	0.65	0.61-3.00	-0.28	-0.84
Task-switching (Cognitive Flexibility)					
Letter Accuracy (Control)	38.07	2.09	28-40	-2.17	6.70
Letter Accuracy RT (Control)	0.83	0.20	0.51-1.90	2.22	8.17
Letter Error (Control)	1.90	2.09	0-12	2.19	6.80
Letter Error RT (Control)	0.68	0.65	0-3.35	1.60	3.92
Number Accuracy (Control)	37.59	2.34	26-40	-2.44	7.95
Number Accuracy RT (Control)	0.82	0.18	0.61-1.82	2.43	9.46
Number Error (Control)	2.41	2.34	0-14	2.44	7.95
Number Error RT (Control)	0.72	0.47	0-2.63	1.43	4.03
Number & Letter Mix trial Accuracy	73.05	6.87	47-80	-1.90	3.85
Mixed Accuracy RT	0.87	0.17	0.62-1.82	2.19	8.32
Mixed Error	6.84	6.87	0-33	1.92	3.92
Mixed Error RT	1.24	0.54	0-2.70	-0.10	0.53

Note: Only the italicized process scores were used in the hypothesis testing; Go No-Go accuracy scores are collectively for Go and No-Go trials; RT = Response time in seconds; Ave. = Average, WA = Weighted Average; 5 D = 5 distractors, 10 D = 10 distractors, 15 D = 15 distractors, and 20 D = 20 distractors. [a] = Task timed out, no RT.

On Go No Go task, 95.5% participants (*n* = 105) obtained the maximum score of 50 (total 50 trials) and made no errors on the Go trials. A total of 27.3% (*n* = 30) responded accurately on the No-Go trials and obtained a maximum score of 20. Notably, participants' RT was greater for the Go Correct trials (*M* = 0.38, *SD* = 0.06) than the No-Go error RT (*M* = 0.25, *SD* = 0.22). Of note, Go No-Go and 2-Back tasks had smaller inter-stimulus intervals (ISI) than Visual Search task and Task Switching (ISI Go No-Go < 2-Back < Visual Search <Task

Switching). According to Hair et al. (2010) and Byrne (2010), data is deemed normal if the skewness is between 2 and +2 and the kurtosis is between 7 and +7. Although inspection of the error score and histogram curve revealed some nonnormal kurtosis; however, because of the resilience of this sort of departure from normalcy, it was deemed acceptable (Table 5) except for the Visual Search accuracy score (explained below).

For the purpose of hypothesis testing, we utilized the accuracy scores of each EF task (Go No-Go cumulative accuracy, Visual Search Accuracy, 2-Back cumulative accuracy, and Task Switching letter and number mix trial accuracy). Exploratory hierarchical analyses were conducted using the response time for only the Go trial accuracy response time of the Go No-Go task, Visual Search accuracy response time, Match accuracy response time for the 2-Back task, and mixed set (letter and number combined) accuracy response time for the Task Switching. The response time on the Go trials is comparable to Cascio et al.'s (2022) study with 16 to 17 years old male participants. On Go trials, their average reaction time varied from 0.26 to 0.54 seconds (*M* = 0.38 seconds, *SD* = 0.04 seconds). Similarly, adults in the Jonkman et al.'s (2003) study, young adults (between 19 and 23 years) had an accuracy score of 99 (*SD* = 1.8) with 0.40 seconds response time (*SD* = 0.08).

Table 6

Descriptive Statistics for Theory of Mind Variables

Theory of Mind Variables	M	SD	Range	Skewness	Kurtosis
First Order ToM					
FB Belief Task	11.57	0.82	8-12	-2.34	6.09
FB Desire Task	11.70	0.57	9-12	-2.07	4.83
FB Physical People Task (Control)	11.75	0.74	7-12	-3.94	18.59
FB Task Combined (Belief and Desire)	23.27	1.12	17-24	-2.66	10.17
Second-Order ToM					
SS Control Task	15.87	0.43	14-16	-3.52	11.77

(table continues)

Theory of Mind Variables	M	SD	Range	Skewness	Kurtosis
SS Mental State Task	12.44	2.55	2-16	-1.26	2.62
Self-Report Theory of Mind					
ToMI-SR-Adult	15.43	2.28	9.53-19.70	-0.50	-0.45
Interpersonal Decentering					
Average Number of Interactions	1.94	0.72	.75-5	.94	1.97
Highest Score Across Stories (Best Effort)	7.81	1.91	2-9	-1.50	1.28
Average of Highest Scores Across Stories	5.49	1.80	1.67-9	-.05	-.54
Average of Average Scores Across Stories	4.25	1.32	1.67-7.50	.27	-.48

Note: Only the italicized process scores were used in the hypothesis testing; B = False Belief; SS = Strange Stories; TOMI-SR-Adult = Theory of Mind Inventory Self Report Adult

As expected, on the first-order ToM task, FB, more than 50% of participants obtained a maximum score of 12 (Table 6). As such, 71.8% (*n* = 79) participants on the Belief category, 74.5% (*n* = 82) participants on the Desire category, and 84.5% (*n* = 93) on the Physical People category demonstrated ceiling effect. Any performance variability on the False Believe task is likely attributable to distractibility, low motivation, or other test-taking factors. A total of 90.9% of participants (*n* = 100) accurately performed the Strange Stories controlled comprehension task and obtained a maximum score of 16. However, for the Strange Story Mental State Task, only 6.4% (*n* = 7) of participants obtained a maximum score of 16. Nonetheless, 50% of participants scored between 13 and 16 (50^{th} percentile = 13 and 75^{th} percentile = 14).

Associations among Demographic Variables

This study included a comprehensive list of demographic variables and gathered information regarding the most commonly assessed variables (age, sex at birth, gender identity, sexual orientation, relationship status, ethnicity, religious affiliation, educational information regarding self and parents, employment, and socioeconomic status, and the number of siblings and children) and empirically relevant health history variables (English proficiency, handedness, use of prescription glasses, seizure and head injury history, and preexisting diagnosis of mental health, ASD, and ADHD). They were referred to as demographic and health history variables in the data analyses.

Among demographic variables, only the number of siblings was significantly but negatively associated with SES, $r = -.32$, $p<.001$ in our sample. However, significant relationship was observed between ethnicity and SES, $F(4,101) = 2.84$, $p = .028$, $\eta^2 = .10$. Post hoc analysis using Least Significant Difference (LSD) revealed that SES was significantly different between African Americans ($M = 2.89$, $SD = 1.08$) and Asian Americans ($M = 3.58$, $SD = .84$; $p = .031$, 95% C.I. = [-1.32, -.06]), African Americans and European/White ($M = 3.50$, $SD = .86$; $p = .028$, 95% C.I. = [-1.16, -.07]), Asian Americans and Latino American/Hispanic ($M = 2.77$, $SD = 1.30$; $p = .021$ 95% C.I. = [.12, 1.50]), and European/White and Latino American/Hispanic ($p = .020$, 95% C.I. = [.12, 1.34]). No other demographic variables were significant. Descriptive analysis found no other significant association between other demographic variables.

Association between Demographics and Variables of Interest

Demographic variables were examined as possible covariates with the study variables, EF and ToM. Performance on all the EF tasks was unrelated to group differences in ethnicity, religious affiliation, relationship or employment status, language (between monolingual and bilingual English speakers), seizure history, and ASD. None of the ToM tasks (FB, Strange Stories, or TOMI-SR) demonstrated significant group differences for sex assigned at birth, gender identity, sexual orientation, relationship status, ethnicity, religious affiliation, or employment status, participants with and without the use of prescription glasses, ADHD, seizure history, medication, and head injury except as described below.

Visual Search Task (Attention)

Among the demographic variables, only father's education was positively associated with Visual Search task, $r = .22$, $p = .024$. On this task, participants with no prescription glasses ($n = 38$, $M = 1.24$, $SD = .31$) performed better than those with prescription glasses ($n = 72$, $M = 1.12$, $SD = .23$) as significant group differences were observed on this task, $t(108) = -2.34$, $p = .021$, $d = -.468$. Participants with no MH diagnosis ($n = 62$, $M = 1.22$, $SD = .31$) scored higher on the Visual Search task than those with a MH diagnosis ($n = 48$, $M = 1.08$, $SD = .16$) as significant group differences were observed on this variable, [homogeneity of variance not assumed, $F(108) = 12.59$, $p < .001$; $t(94.52) = -3.15$, $p = .002$, $d = -.56$]. Significant group differences were also noted between participants with and without head injury on the Visual Search Task [homogeneity of variance not assumed, $F(108) = 5.42$, $p = .022$; $t(15.75) = 2.80$, $p = .013$, $d = .489$]. Participants with no known history of head injury ($n = 102$, $M = 1.17$, $SD = .17$) scored higher than those with a history of head injury ($n = 8$, $M = 1.04$, $SD = .11$) on this variable.

Go No-Go Task (Inhibition)

Go No-Go task was positively associated with only SES, $r = .24$, $p = .013$, and no other demographic or health history variables.

2-Back Task (Working Memory)

Two-Back task was positively associated with age, $r = .22$, $p = .020$, and participants' completed education, $r = .22$, $p = .022$. On this task, there were significant group differences for birth sex, $t(108) = 2.28$, $p = .025$, $d = .511$. Participants whose birth sex was male ($n = 26$, $M = 88.96$, $SD = 6.72$) performed significantly better on the 2-Back task than those whose assigned birth sex was female ($n = 84$, $M = 84.64$, $SD = 8.90$). Similarly, cisgender men ($n = 26$, $M = 88.76$, $SD = 6.78$) and cisgender women ($n = 84$, $M = 84.40$, $SD = 9.10$) differed significantly on the 2 Back task, *t*(108) = 2.20, *p* = .031, *d* = .509. The two-Back task was not significantly associated with sexual orientation or with any other demographic variable.

Task Switching (Cognitive Flexibility)

Participants did not significantly differ on any demographic variables on Task Switching. For the health history variables, participants with no known MH diagnosis (*n* = 62, *M* = 74.34, *SD* = 5.14) scored higher than those with a MH diagnosis (*n* = 48, *M* = 71.38, *SD* = 8.37) and this difference was significant [homogeneity of variance not assumed, *F*(108) = 8.42, *p* = .004; *t*(73.63) = -2.16, *p* = .034, *d* = -.44].

Before running the hypothesis testing, significantly associated demographic variables with the EF variables were controlled for. The Visual Search task was controlled for prescription glasses, history of head injury, and mental health history, Go No-Go task was controlled for SES, Two-Back (2-Back) task was controlled for gender identity (dummy coded) age, education, and MH history.

False Belief

False Belief task was not significantly associated with any demographic or health history variable.

Strange Stories

No significant demographic or health history differences were noted for the Strange Stories task except for the number of siblings, which was negatively associated with the number of siblings, *r* = -.22, *p* = .019. Significant group differences were observed between monolingual and bilingual English speakers on Strange Stories task [homogeneity of variance not assumed, *F*(108) = 4.88, *p* = .029; *t*(37.86) = 2.26, *p* = .030, *d* = .59] as monolingual English speakers (*n* =

80, *M* = 12.84, *SD* = 2.08) scored higher than the bilingual English speakers (*n* = 30, *M* = 11.37, *SD* = 3.33). Since monolingual participants demonstrated linguistic advantage and we did not specifically assess verbal abilities (a limitation of this study), participants' self-reported English fluency was added as a predictor in hypothesis testing models.

TOMI-SR

TOMI-SR was positively correlated with participants' current education, $r = .37$, $p <.001$, completed education, $r = .30$, $p = .001$, and father's education, $r = .19$, $p = .047$. TOMI-SR also positively associated with participants' age, $r = .26$, $p = .005$. Since age and education demonstrated significant association, we only controlled for the current education in our hypothesis testing models. No significant differences were observed for any other demographic characteristic on TOMI-SR. For the health history variables, participants with suspected/diagnosed ASD (*n* = 15, *M* = 13.70, *SD* = 2.31) differed significantly from those with no ASD diagnosis (*n* = 95, *M* = 15.71, *SD* = 2.16) on TOMI-SR, $t(108) = 3.31$, $p = .001$, $d = .92$. Conversely, on TOMI-SR, participants with diagnosed MH condition (*n* = 48, *M* = 16.25, *SD* = 2.17) performed well and significantly differed [$t(108) = 3.47$, $p < .001$, $d = .667$] from participants not diagnosed with MH condition (*n* = 62, *M* = 14.80, *SD* = 2.17).

Interpersonal Decentering

None of the Interpersonal Decentering process scores were significantly associated with any demographic variables (all *p*s >.05) except for SES, the number of siblings, sex assigned at birth, and gender identity as outlined below. Only the Interpersonal Decentering average number of interactions was positively associated with SES, $r = .21$, $p = .027$, and negatively associated with number of siblings, $r = -.21$, $p = .029$. There were significant group differences for sex assigned at birth (Table 7) and gender identity (Table 8) on the Interpersonal Decentering.

Table 7

Group Differences Between Sex Assigned at Birth on Interpersonal Decentering Process Scores (Male = 26, Female = 84)

Measures	Male Means (SD)	Female Means (SD)	T Values *t*(108)	Cohen's d
Average Number of Interactions	1.58 (.54)	2.05 (.73)	-3.03, p = .003	-.679
Highest Score Across Stories (Best Effort)[a]	6.65 (2.38)	8.17 (1.59)	-3.04, p = .005	-.839
Average of Highest Scores Across Stories	4.54 (2.00)	5.78 (1.64)	-3.19, p = .002	-.716
Average of Average Scores Across Stories	3.72 (1.33)	4.41 (1.28)	-2.38, p = .019	-.533

Note: [a] homogeneity of variance not assumed, Levene's F= 10.13, p =.002, adjusted df = 32.18.

Table 8

One-Way Analysis of Variance of Interpersonal Decentering (ID) by Gender Identity

Interpersonal Decentering	*n*	Means (SD)	*F*	*p*	*Eta Squared*
Average Number of Interactions					
Cisgender Men	25	1.58 (.55)	4.22	.017	.073
Cisgender Women	73	2.04 (.75)			
Self-Identified Gender Identity	12	2.02 (.60)			
Highest Score Across Stories[a]					
Cisgender Men	25	6.76 (2.37)	5.93	.004	.100
Cisgender Women	73	8.21 (1.60)			
Self-Identified Gender Identity	12	7.58 (1.88)			
Average of Highest Scores					
Cisgender Men	25	4.61 (2.01)	4.73	.011	.081
Cisgender Women	73	5.83 (1.66)			

(table continues)

Self-Identified Gender Identity	12	5.21 (1.63)			
Average of Average Scores					
Cisgender Men	25	3.77(1.34)	2.25	.110	.040
Cisgender Women	73	4.41(1.26)			
Self-Identified Gender Identity	12	4.24(1.49)			

Note:[a] = Equal Variances Not Assumed

Posthoc analyses for gender identity using Games-Howell indicated that cisgender men and cisgender women significantly differed on all Interpersonal Decentering process scores except for average of average scores across stories. No significant differences were observed for the self-identified gender identity category (see Table 8).

For the health history variables, participants who did not use prescription glasses had higher Interpersonal Decentering average number of interactions (M = 2.13, SD = .69) than those with prescription glasses (M = 1.84, SD = .72), t(108) = -2.03, p =.045. Significant group differences were observed for ASD, [homogeneity of variance not assumed, F= 4.03, p = .047; t(28.41) = 2.84, p = .008, d = .549]. Participants with diagnosed or suspected ASD had lower Interpersonal Decentering number of interactions (M = 1.60, SD = .44) than individuals who were not diagnosed or suspected of having ASD (M = 1.99, SD = .74). Significant group differences were noted for participants with and without MH diagnosis on Interpersonal Decentering highest score across stories, [homogeneity of variance not assumed, F= 17.30, p <.001; t(101.98) = 2.42, p = .017, d = .437] as participants with MH diagnoses scored higher (N = 48, M = 8.27, SD = 1.32) than those without MH diagnosis (N = 62, M = 7.45, SD = 2.21). However these demographic and health variables were not significantly associated with Interpersonal Decentering maturity, Average of Average scores across stories, and they were not controlled for in the hierarchical multiple regression model.

For the Interpersonal Decentering variable, historically, there is a strong association between the number of interactions observed in a given story (a proxy for story length) with the Highest Decentering score (best effort), $r = .36$ $p<.001$, and Highest Score Average here, $r = .51$, $p < .001$ (Table 7). Hence, these scores were not analyzed further. However, number of interactions and Average of Average scores are not significantly correlated, $r = .12$, $p = .195$, and hypothesis testing was conducted only with the Interpersonal Decentering Average of Average scores across stories to avoid multicollinearity.

Bivariate Associations among Study Variables of Interest

Bivariate association among EF tasks (see Table 9) showed significant associations but only between Task Switching and Go No-Go task, $r = .23$, $p = .015$, and Task Switching and 2-Back task, $r = .41$, $p <.001$.

Table 9

Bivariate Associations among EF Tasks

	EF Tasks	1	2	3	4	5	6	7	8
1	Visual Search Accuracy	-							
2	Go No-Go Accuracy	-.03	-						
3	2-Back Accuracy	-.08	.08	-					
4	Task Switching Accuracy	-.08	.23*	.41**	-				
5	Go Accuracy RT	-.01	.34**	-.10	-.14	-			
6	Visual Search RT	.38**	.14	-.11	-.30**	.39**	-		
7	2-Back Match RT	.07	.14	.04	.06	.26**	.16	-	
8	Task Switching RT	.05	-.08	-.18	-.35**	.16	.28**	-.01	-

Note:**. Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed). RT = Response Time

Among ToM tasks (Table 10), False Belief task was positively and significantly associated with the Strange Stories task, $r = .38$, $p <.001$. TOMI-SR-A was significantly associated with only Interpersonal Decentering Average number of interactions *r* = .21, *p* = .026 and no other Interpersonal Decentering process scores, False Belief or the Strange Stories task (see Table 10).

The association between EF tasks and ToM task (Table 11) was significant for 2-Back and Strange Stories task, *r* = .35, *p* <.001, 2-Back and TOMI-SR-A task, *r* = .20, *p* =.037, and between Task Switching and Strange Stories task, *r* = .31, *p* = .001 (see Table 11). Interpersonal Decentering highest score across stories (best effort) was positively and significantly associated with Go No-Go task, *r* = .27, *p* = .005.

Table 10

Bivariate Associations Among ToM Tasks

	ToM Tasks	1	2	3	4	5	6	7
1	False Belief Task	-						
2	Strange Stories Task	.38**	-					
3	TOMI-SR-A	-.09	.18	-				
4	Average Number of Interactions	-.01	.13	.21*	-			
5	Highest Score Across Stories (Best Effort)	.15	.11	-.04	.36**	-		
6	Average of Highest Scores Across Stories	.06	.08	-.01	.51**	.77**	-	
7	Average of Average Scores Across Stories	.15	.10	-.09	.12	.70**	.85**	-

*Note:**. Correlation is significant at the 0.05 level. **Correlation is significant at the 0.001 level (2-tailed). TOMI-SR-A = Theory of Mind Inventory Self Report Adult

Table 11

Bivariate Associations Between EF and ToM Tasks

	ToM Tasks	VS	VS RT	GNG	Go RT	2-Back	2B Match RT	TS	TS RT
1	False Belief Task	-.07	-.11	-.08	-.15	.11	.00	.11	-.14
2	Strange Stories Task	-.18	-.17	.10	-.17	.34**	.06	.33**	-.42**
3	TOMI-SR-A	.09	-.01	.02	-.02	.10	-.09	.15	-.15
4	Average Number of Interactions	.20*	.12	.03	-.12	.16	-.06	.03	-.07
5	Highest Score Across Stories (Best Effort)	-.04	.16	.27**	.20*	.10	.20*	-.01	-.04
6	Average of Highest Scores Across Stories	.01	.12	.11	.12	.12	.19*	-.01	.02
7	Average of Average Scores Across Stories	-.14	-.03	.12	.15	.09	.24*	-.03	-.01

Note: **. Correlation is significant at or less than 0.001 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed). TOMI-SR-A = Theory of Mind Inventory Self Report Adult

Hypothesis Testing

The assumptions for running hierarchical multiple regression were tested for each hypothesis before running analyses (see Tabachnick & Fidell, 2007). Overall, the residual plots indicate the violation of the independent error assumption for the Go No-Go and Visual Search tasks plotted against each outcome variable for scatter plot assessing the linear relationship between each predictor and outcome variables. Hence, the analyses should be interpreted with caution. Each multivariate assumption is outlined under its respective hypothesis. For all the hierarchical regression, demographic and health predictor variables were included in the regression models only when they were substantially and theoretically associated with the dependent variables to prevent an unwarranted decrease in statistical power.

Hypothesis 1

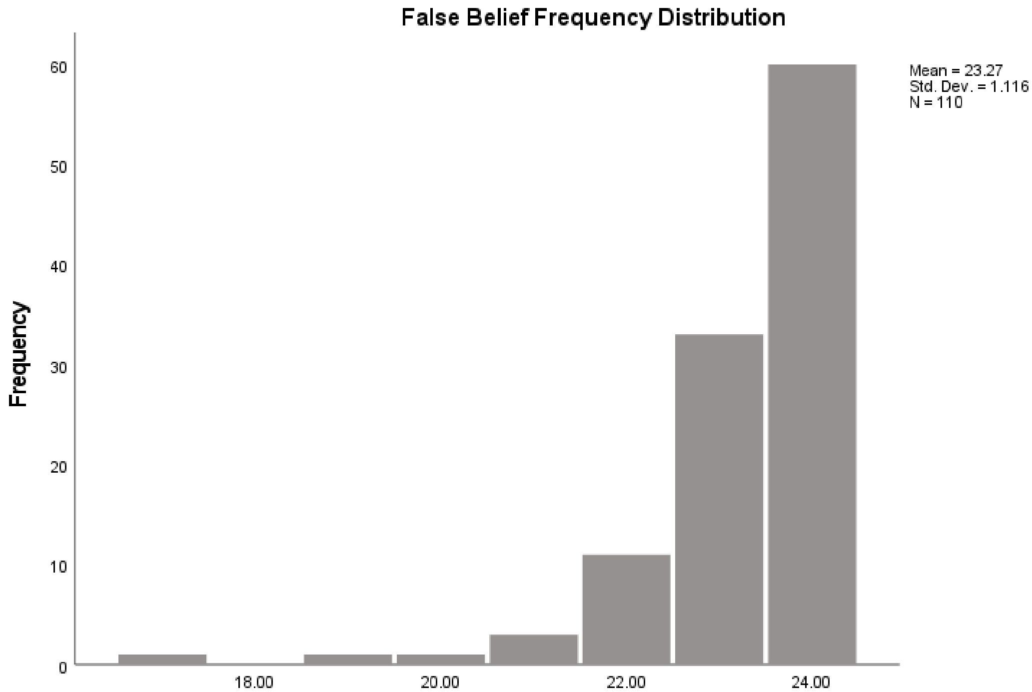
> *Working memory and cognitive flexibility will predict performance on False Belief after controlling for demographic and EF variables of attention and inhibition.*

The False Belief task had a ceiling effect (Maximum = 12, skewness = -2.66, kurtosis = 10.17), and did not meet the assumptions for running regression analysis (linear relationship, multivariate normality, homoscedasticity). However, Keith (2015) asserted that if a large number of participants perform better on a task, then graphing the data is reasonable to demonstrate the performance on a particular outcome variable (see Figure 2).

Hierarchical multiple regression was performed (see P-P plot Appendix F) to explore significant predictors of first-order ToM, False Belief task. Basic EF variables (Go No-Go and visual search task) were entered in the first model, and complex EF tasks (Task Switching and 2-Back task) were entered in the second model.

Figure 2

False Belief Means Scores



Note. Histogram representing False Belief mean for the Belief and Desire category combined; Maximum possible score =24.

Table 12 outlines the effect size (R^2), R^2 change, and adjusted R^2 for the first and full model. Table 13 reports unstandardized regression coefficients (*B*) and standardized regression coefficients (β). Our full hierarchical model predicting ToM as measured through False Belief was not significant (p>.05) and did not explain significant variability in False Belief performance for model 1, $F(2, 107) = .610$, $p = .545$. Moreover, model 2 was not significant, $F(4, 105) = .864$, $p = .488$ and the addition of complex EF tasks did not significantly predict the variability in False Belief performance, $\Delta R^2 = .02$, $F(2, 105) = 1.12$, $p = .332$. The R^2 for model 1 and ΔR^2 with *F*-change for block 2 suggest that EF abilities did not significantly improve the model prediction. Hence, our hypothesis was not supported.

Table 12

Hypothesis 1: Summary of Hierarchical Regression Analysis Model for Variables Predicting False Belief

Predictors	R	R^2	ΔR^2	Adj. R^2	F	Sig	F Change	F Change Sig
Basic EF (Model 1)	.11	.01	.01	-.01	.61	.545	.61	.545
Complex EF (Model 2)	.18	.03	.02	-.01	.86	.488	1.12	.332

Note: ΔR^2 = R^2 Change; Simple EF = Go No-Go & Visual Search; Complex EF

Table 13

Hypothesis 1: Predictors of False Belief Task From Hierarchical Regression Model

Predictors		B	t	Sig (B)	β
Model 1	Visual Search	-.08	-.70	.489	-.07
	Go No-Go	-.09	-.87	.388	-.08
Model 2	Visual Search	-.05	-.43	.665	-.04
	Go No-Go	-.12	-1.09	.278	-.11
	2-Back	.09	.75	.451	.08
	Task Switching	.13	1.11	.271	.11

Hypothesis 2

Working memory and cognitive flexibility will predict performance on Strange Stories after controlling for demographic and EF variables of attention and inhibition.

First, multiple regression analysis Backward Elimination Method was performed between Strange Stories as the criterion variable and all the significantly associated demographic variables of age, gender identity (dummy coded as 0 and 1), SES, current education, English fluency, number of siblings, use of prescription glasses, and history of head injury as the predictor variables before performing hypothesis testing. This step was performed to exclude demographic predictors that did not predict significant unique variability in Strange Stories and to assist in assessing the empirically driven effects once the redundant predictor variables are statistically eliminated. Multiple regression analysis revealed that English fluency, $t(99) = 2.75$, p .007, β =.26, and number of siblings, $t(99) = -2.34$, p .021, β =-.24, indicated significant unique association with Strange Stories. Hence, these two variables were added to the hypothesis testing models to account for their variability in the model.

Next, Strange Stories task was assessed first to explore the assumptions of multiple regression analysis. Plots between standard predicted values and standard residuals for each EF variable predicting the outcome variable of Strange Stories noted some divergence from linearity assumption for the Go No-Go and Visual Search tasks upon visual inspection. The multicollinearity assumption was met; the highest correlation between predictor variables was $r = .41$. Collinearity statistics (VIF and Tolerance) also indicated our variables were not highly correlated as VIF was below 10 and tolerance scores were above 0.2. Durbin-Watson's statistic was 1.71, indicating that the values of the residuals are independent and within the expected range. Cook's distance statistics did not reveal any influential cases biasing our model. The scatter plot of our model's standardized value against standardized residual indicated that the data likely violated the homoscedasticity assumption. The values of residuals on the P-P plot appear to be normally distributed (Hair et al.,1998; Pallant, 2007).

Lastly, hierarchical regression analysis was performed to assess the variability on the Strange Stories as predicted from demographic, simple EF, and complex EF tasks. The following models were tested: 1) English fluency and number of siblings were controlled for by adding them to the regression model in the first block in the regression model, 2) Basic EF tasks of Accuracy scores for the Go No-Go and Visual Search in the second block, and 3) 2-Back and Task Switching in the third block as predictor variables. Table 14 outlines the effect size (R^2), R^2

change, and adjusted R^2 for the first, second, and full model. Table 15 reports unstandardized regression coefficients (*B*) and standardized regression coefficients (β) and provides the unique contribution of each predictor variable across each hierarchical model.

Table 14

Hypothesis 2: Summary of Hierarchical Regression Analysis Model for Variables Predicting Strange Stories

Predictors	R	R^2	ΔR^2	Adj. R^2	F	Sig	F Change	F Change Sig
Demographics (Model 1)	.33	.11	.11	.09	6.61	.002		
Simple EF (Model 2)	.39	.16	.05	.12	4.80	.001	2.78	.067
Higher EF (Model 3)	.51	.27	.11	.23	6.20	<.001	7.75	<.001

Note: $\Delta R^2 = R^2$ Change

Table 15

Hypothesis 2: Predictors of Strange Stories Task from Hierarchical Regression Model

Predictors		B	t	Sig (B)	β
Model 1	English Fluency	1.40	2.69	.008	.25
	Siblings	-.43	-2.29	.024	-.21
Model 2	English Fluency	1.50	2.91	.004	.26
	Siblings	-.40	-2.81	.031	-.20
	Visual Search	-.47	-1.99	.049	-.18
	Go No-Go	.28	1.22	.225	.11
Model 3	English Fluency	1.27	2.58	.011	.22
	Siblings	-.27	-1.54	.127	-.13
	Visual Search	-.32	-1.43	.156	-.12
	Go No-Go	.17	.76	.451	.07
	2-Back	.68	2.96	.004	.26
	Task Switching	.47	2.02	.046	.19

The analyzed hierarchical model predicting Strange Stories with demographic variables accounted for a significant amount of variance, $\Delta R^2 = .11$, $F(2,107) = 6.61$, $p = .002$. Although the addition of basic EF task predictors of Go No-Go and Visual Search increased the variance accounted for in Strange Stories, $F(4, 105) = 4.80$, $p = .001$, this addition was not significant, $\Delta R^2 = .05$, $F(2, 105) = 2.78$, $p = .067$. With the addition of Task Switching and 2-Back task to the model, the final block led to another significant increase in the variance accounted for in Strange Stories, $F(6,103) = 6.20$, $p < .001$. The third model was indeed significant $\Delta R^2 = .11$, $F(2, 103) = 7.75$, $p < .001$, and explained additional 10% variability predicting Strange Stories (see Table 14).

The final (third model) included all our predictor variables, but the number of siblings, Go No-Go, and Visual Search task were not significant unique predictors in the final model ($p > .05$). The best predictor of ToM as assessed by the Strange Stories task was the 2-Back task ($\beta = .26$), followed by English fluency ($\beta = .22$) and then Task Switching ($\beta = .19$). All the significant variables collectively explained the 27% variance in Strange Stories (Table 14). The ΔR^2 and *F*-change for block 3 in our model suggest that the addition of 2-Back and Task Switching improved the model prediction for explaining Strange Stories performance. Hence, our hypothesis was supported.

Hypothesis 3

EF abilities of working memory and cognitive flexibility will predict TOMI-SR-Adult after controlling for significant demographic, attention, and inhibition variables.

Multiple regression analysis Backward Elimination Method for TOMI-SR Adult as the criterion variable was performed with significantly correlated demographic variables for selecting the predictors for the hierarchical regression analysis. After removing father's education since it did not significantly contribute to the variability, participants' education, $t(99)$

= 3.39, p = .001, β = .36, MH, t(99) = 3.39, p <.001, β =.28, and ASD, t(99) = -4.09, p <.001, β =-.35, were found to significantly predict responses on TOMI-SR, and were controlled for by adding them to the regression models of the hypothesis testing.

For testing multivariate analysis assumptions, plots between standard predicted values and standard residuals for each EF variable predicting TOMI-SR noted nonnormal linearity for the Go No-Go and Visual Search tasks upon visual inspection. The assumption of multicollinearity was met as assessed through correlational analysis and collinearity statistics (VIF and Tolerance) which were found to be in an expected range. Durbin-Watson's statistic was 1.93, indicating that the values of the residuals are independent and within the expected range. Cook's distance statistics showed no multivariate outliers. The scatter plot of our model's standardized value against standardized residual indicated a potential violation of homoscedasticity. The values of residuals on the P-P plot appeared to be normally distributed.

Table 16

Hypothesis 3: Summary of Hierarchical Regression Analysis for Variables Predicting TOMI-SR Adult

Predictors	R	R^2	ΔR^2	Adj. R^2	F	Sig	F Change	F Change Sig
Demographics (Model 1)	.58	.34	.34	.32	17.80	<.001		
Simple EF (Model 2)	.59	.35	.02	.32	11.28	<.001	1.34	.266
Higher EF (Model 3)	.60	.36	.008	.32	8.20	<.001	.677	.510

Note: ΔR^2 = R^2 Change

Hierarchical multiple regression was performed to explore significant predictors of self-reported ToM (TOMI-SR). Significantly associated demographic variables (education, MH, and ASD diagnosis) were entered in the first model, followed by basic EF variables (Go No-Go and visual search task) in the second model, and complex EF tasks (Task Switching and 2-Back task) entered in the final model (Table 16). Only the current education (β = .37, p <.001), ASD condition (β = -.35, p<.001) and MH diagnosis (β = .29, p<.001) remained the significant predictors (Table 17) in the final model and collectively accounted for 34% variability in self-reported ToM (Table 16). The ΔR^2 and F-change for block 2 and 3 in our model suggest that EF abilities did not significantly improve the model prediction. Hence, our hypothesis was not supported.

Table 17

Hypothesis 3: Predictors of TOMI-SR Adult Task from Hierarchical Regression Model

Predictors		B	t	Sig (B)	β
Model 1	Education	.51	4.49	<.001	.36
	ASD	-2.38	-4.52	<.001	-.36
	MH	1.36	3.70	<.001	.30
Model 2	Education	.53	4.54	<.001	.38
	ASD	-2.39	-4.31	<.001	-.36
	MH	1.36	3.59	<.001	.30
	Visual Search	.29	1.75	.116	.13
	Go No-Go	-.07	-.49	.693	-.03
Model 3	Current Edu	.52	4.54	<.001	.37
	ASD	-2.32	-4.31	<.001	-.35
	MH	1.33	3.59	<.001	.29
	Visual Search	.33	1.75	.083	.14
	Go No-Go	-.09	-.49	.629	-.04
	2-Back	.18	.92	.358	.08
	Task Switching	.10	.50	.617	.04

Hypothesis 4

EF abilities of working memory and cognitive flexibility will predict Interpersonal Decentering after controlling for significant demographic and attention and inhibition variables.

Multiple regression analysis Backward Elimination Method with self identified gender, SES, number of siblings, use of prescription glasses, ASD, and MH revealed that only sex assigned at birth was significantly associated with Interpersonal Decentering, $t(104) = -2.18$, $p < .031$, $\beta = -.21$, and was treated as a control variable in the subsequent regression models along with the EF tasks.

Before running regression analysis, multiple regression analysis assumptions were carried out. Visual analysis of plots between standard predicted values and standard residuals for each EF variable indicating Interpersonal Decentering revealed some deviation from the linearity assumption for the Go No-Go and Visual Search tasks. The multicollinearity assumption was met with r =.41 as the most significant correlation between predictor variables. Collinearity statistics indicated that VIF was below 10 and tolerance scores were above 0.2. The residuals values were independent and within the predicted range, according to the Durbin-Watson statistic of 2.03. Cook's distance did not indicate multivariate outliers in our sample. The scatter plot of our model's standardized value vs. standardized residual shows general homoscedasticity. On the P-P plot, the residual values seem to be normally distributed.

Hierarchical multiple regression was performed to explore significant predictors of ToM as assessed by Interpersonal Decentering. The significantly associated demographic variable (sex assigned at birth) was entered in the first model, Basic EF variables (Go No-Go and visual search task) were entered in the second model, and finally, complex EF tasks (Task Switching and 2-Back task) were entered in the final model.

Table 18 outlines the effect size (R^2), R^2 change, and adjusted R^2 for the first, second, and full model. Table 19 reports unstandardized regression coefficients (*B*) and standardized regression coefficients (β). In the full hierarchical model predicting ToM as measured through

Interpersonal Decentering, only sex assigned at birth (β = -.24, p =.014) remained a significant predictor (Table 19) in the final model and accounted for 5% variability in Interpersonal Decentering (Table 18). The ΔR^2 and F-change for block 2 and 3 in our model suggest that EF abilities did not significantly improve the model prediction to explain variability in Interpersonal Decentering.

Table 18

Hypothesis 4: Summary of Hierarchical Regression Analysis for Variables Predicting Interpersonal Decentering

Predictors	R	R^2	ΔR^2	Adj. R^2	F	Sig	F Change	F Change Sig
Demographics (Model 1)	.22	.05	.05	.04	5.65	.019		
Simple EF (Model 2)	.27	.07	.02	.05	2.83	.042	1.40	.251
Higher EF (Model 3)	.32	.11	.03	.06	2.43	.040	1.76	.177

Note: $\Delta R^2 = R^2$ Change

Table 19

Hypothesis 4: Predictors of Interpersonal Decentering Task From Hierarchical Regression Model

Predictors		B	t	Sig (B)	β
Model 1	Sex assigned at Birth	-.69	-2.38	.019	-.22
Model 2	Sex assigned at Birth	-.63	-2.16	.033	-.21
	Visual Search	-.62	-1.34	.184	-.13
	Go No-Go	.07	.97	.334	.09
Model 3	Sex assigned at Birth	-.75	-2.50	.014	-.24
	Visual Search	-.61	-1.33	.188	-.12
	Go No-Go	.08	1.13	.261	.11
	2-Back	.03	1.64	.105	.17
	Task Switching	-.03	-1.51	.134	-.16

Exploratory Analyses Using Reaction Times of EF Tasks as Predictors

Lastly, exploratory regression analyses were not significant for any model predicting ToM from EF skills response time (Tables 20, 21, 22). However, 2-Back accuracy response time (Table 23) was the only significant predictor of Interpersonal Decentering (β = .22, p =.030).

Table 20

Exploratory Multiple Regression Analysis EF Task Reaction Time Predicting False Belief

Predictors	**B**	**95% CI for B**		**t**	**Sig (B)**	**β**
		Lower	**Upper**			
VS Accuracy RT (WA)	-.45	-1.65	.75	-.74	.458	-.08
Go Accuracy RT	-2.40	-6.43	1.63	-1.18	.240	-.12
2-B Match Accuracy RT	.28	-1.22	1.77	.37	.712	.04
TS Mixed Trial Accuracy RT	.13	-.29	.55	.61	.546	.06

Note: N = 110; F(4, 105) = .80, p =.531, R^2 = .03, R^2_{adj} = -.01.VS = Visual Search; TS = Task Switching; WA = Weighted Average; RT = Response Time

Table 21

Exploratory Multiple Regression Analysis EF Task Reaction Time Predicting Strange Stories

Predictors	**B**	**95% CI for B**		**t**	**Sig (B)**	**β**
		Lower	**Upper**			
VS Accuracy RT (WA)	-1.12	-3.80	1.57	-.82	.412	-.09
Go Accuracy RT	-7.01	-16.03	2.02	-1.54	.127	-.16
2-B Match Accuracy RT	2.25	-1.11	5.60	1.33	.187	.13
TS Mixed Trial Accuracy RT	-.62	-1.56	.32	-1.32	.191	.13

Note: N = 110; F(4, 105) = 1.93, p = .111, R^2 = .07, R^2_{adj} = .03. VS = Visual Search; TS = Task Switching; WA = Weighted Average; RT = Response Time

Table 22

Exploratory Multiple Regression Analysis EF Task Reaction Time Predicting TOMI-SR

Predictors	**B**	**95% CI for B**		**t**	**Sig (B)**	**β**
		Lower	**Upper**			
VS Accuracy RT (WA)	.10	-2.38	2.57	.01	.938	.01
Go Accuracy RT	-.09	-8.40	8.22	-.02	.982	-.00
2-B Match Accuracy RT	-1.38	-4.46	1.71	-.09	.377	-.09
TS Mixed Trial Accuracy RT	-.00	-.87	.86	-.00	.996	-.00

Note: N = 110; F(4, 105) = .21, p = .931, R^2 = .008, R^2_{adj} = -.03. VS = Visual Search; TS = Task Switching; WA = Weighted Average; RT = Response Time

Table 23

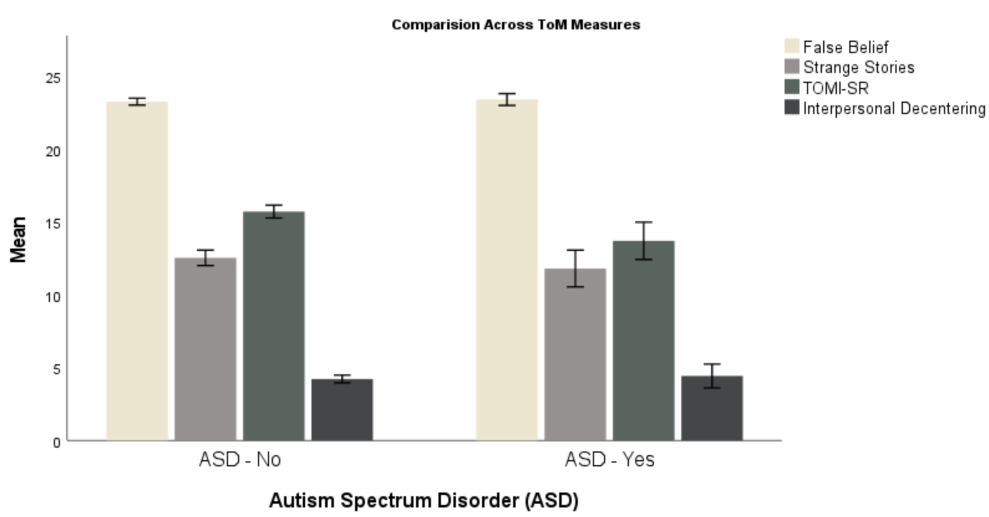
Exploratory Multiple Regression Analysis EF Task Reaction Time Predicting Interpersonal Decentering

Predictors	B	95% CI for B		t	Sig (B)	β
		Lower	Upper			
VS Accuracy RT (WA)	-.98	-2.35	.40	-1.41	.161	-.15
Go Accuracy RT	3.25	-1.37	7.87	1.40	.166	.15
2-B Match Accuracy RT	1.91	.19	3.62	2.20	.030	.22
TS Mixed Trial Accuracy RT	.23	-.25	.71	.94	.351	.09

Note: N = 110; F(4, 105) = 2.48, p = .049, R^2 = .09, R^2_{adj} = .05. VS = Visual Search; TS = Task Switching; WA = Weighted Average; RT = Response Time

Figure 3

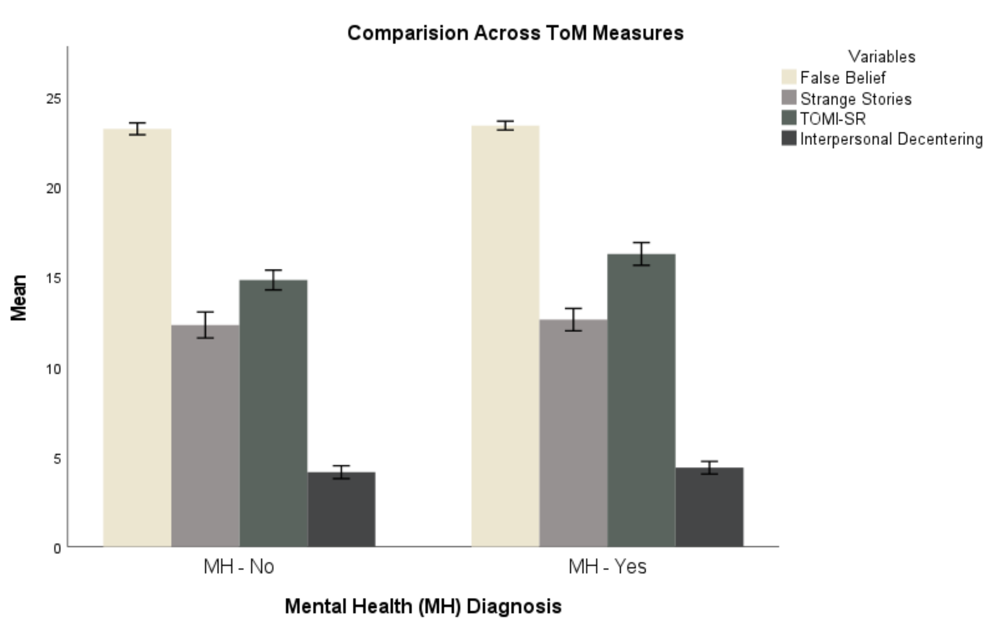
ToM Variability across Measures for ASD



Note. Graph representing variability across ToM measures in participants with and without ASD

Figure 4

ToM Variability across Measures for MH



Note. Graph representing variability across ToM measures in participants with and without MH diagnosis

CHAPTER 4

DISCUSSION

Theory of Mind (ToM) is the cognitive ability to discern and assign mental states to others, such as their thoughts, intentions, and beliefs. It refers to the understanding that others have mental states that are distinct from one's own and the capacity to draw valid inferences about the content of those mental states. Recent research indicates that ToM and executive functioning are connected components demonstrating concurrent developmental trajectory. The purpose of this study was (a) to determine which EF domains (from basic to complex) predict ToM in a non-clinical adult population and (b) to assess the association between first-order ToM (False Belief), second-order ToM (Strange Stories), self-reported ToM abilities and complex ToM tasks as measured through Interpersonal Decentering. We hypothesized that EF abilities of attention (Visual Search), inhibition (Go No-Go), working memory (2-Back), and cognitive flexibility (Task Switching) would significantly and differently explain social cognitive processes from simple (first-order) to complex (Interpersonal Decentering) ToM tasks. To that end, descriptives and correlational analyses were conducted along with a series of hierarchical regression analyses assessing EF abilities of inhibition, attention, working memory, and cognitive flexibility and empirically selected demographic control variables as predictors of False Belief, Strange Stories, self-reported measure (TOMI-SR), and Interpersonal Decentering as outcome variables.

Main Findings

Go No-Go and Visual Search tasks, and the False Belief task had ceiling effects, and participants obtained near-perfect scores on these measures. Performance on the False Belief task on a two-stage hierarchical model did not demonstrate variability in relation to any EF ability (hypothesis 1). The hierarchical analysis revealed that control variables of English fluency and having siblings, along with Task Switching and 2-Back EF abilities, significantly predicted variability in the Strange Stories task (hypothesis 2). Control variables (participants' education, reportedly diagnosed mental health condition, and ASD) significantly predicted variability in TOMI-SR, but no EF ability did (hypothesis 3). Similarly, birth sex was the only significant predictor of Interpersonal Decentering, but no EF ability (hypothesis 4). Correlational analysis indicated that the False Belief task was significantly associated with the Strange Stories task, whereas self-reported ToM was associated with Interpersonal Decentering average number of interactions, both presumably tapping complex social cognitive and mentalizing processes.

Contradicting our first hypothesis, no EF task was significantly associated with False Belief, perhaps because participants' performance on the False Belief task reached a ceiling. Although findings contradicted our assumptions as we expected to see some association between False Belief and Go No-Go or Visual Search task, it was also expected that participants would obtain a near-perfect score on some of these measures. False Belief task as a measure to assess ToM has been criticized by many researchers (Carpendale & Lewis, 2004; Miller, 2009; Russell et al., 1999). Brent et al.'s (2004) study on children between the ages of 6 and 12 years also noted that participants with ASD performed close to the ceiling on first order ToM tasks (Smarties, False Belief, and Picture Sequencing).

Although the False Belief task has previously been utilized effectively as a measure of mentalizing capacity in children, people with brain injuries, and in brain imaging investigations with healthy and clinical participants, these tasks don't have adequate sensitivity or ecological validity to be used with adults (with or without ASD) for assessing ToM abilities as they unfold in the real world (Carpendale & Lewis, 2004). Perhaps, it is likely that individuals with serious mental illnesses, neurological, and degenerative cognitive difficulties may struggle on first-order ToM task such as False Belief task due to compromised executive and cognitive control (Burns & Patrick, 2007; Shamay-Tsoory & Aharon-Peretz, 2007; Shamay-Tsoory, Tibi-Elhanany, & Aharon-Peretz, 2006), and may demonstrate cortical activation (or lack of) on associated brain regions. In contrast, similar findings may not be replicated with typically developed participants or individuals with no known neurological damage. As highlighted earlier, perspective-taking entails much more than inferring beliefs or false beliefs in young adults, and first-order tasks are not well suited to capture the complete spectrum of mentalizing abilities or distinguish between intact or compromised ToM mechanisms. Although we could not draw any statistical inferences because of the ceiling effect, this attests to our claim that False Belief or any first-order ToM task may not be as sufficiently sensitive measure to expected cognitive complexity crucial for ToM in adults (Jones et al., 2010; Liddle & Nettle, 2006; Slaughter & Repacholi, 2003).

For the second hypothesis, we predicted that 2-Back task and Task Switching would demonstrate incremental variability for explaining performance on Strange Stories. Hierarchical analysis revealed that the 2-Back task and Task Switching, along with English fluency (discussed under ToM and Language) and number of siblings (discussed under Bivariate Association with Demographic Variables), significantly explained variability in the Strange Stories performance, but Visual Search and Go No-Go tasks demonstrated no significant association with Strange Stories. The results indicated the contribution of complex EF abilities (working memory and cognitive flexibility) in explaining mentalizing processes in our participants' Strange Stories performance. Our findings replicated the results reported in the previous studies, as Fischer et al.'s (2017) analysis revealed that EF abilities composite (WAIS Letter Number Sequencing, WAIS Backwards Digit Span, & DKEFS Color-Word Interference) significantly predicted variability in cognitive ToM–Strange Stories and Yoni Cognitive ToM. Although Fischer et al. (2017) discovered a significant relationship between cognitive ToM and EF abilities, the authors used a composite score for both ToM and EF tasks, and did not report the results for the associations between Strange Stories and each EF variable separately as the present study does.

Regarding the associated executive and cognitive processes, the Strange Stories task involves participants identifying the characters' intentions in a sequence of vignettes. The performance demand on this task can be conceptualized as the capacity to provide responses in a flexible manner by keeping the character's intentions in mind before giving a brief response. These processes likely rely on working memory and cognitive flexibility but may not rely on inhibition and visual attention, which explains successful performance on the Strange Stories task attributed to 2-Back and Task Switching. Our findings are comparable with Gökçen et al.'s (2016) study that used a Naturalistic ToM task called the Movie for the Assessment of Social Cognition (MASC; Dziobek et al. 2006) and executive functioning task of cognitive flexibility, Wisconsin Card Sorting Test (WCST), response inhibition using Go No-Go task, and planning ability using a computerized version of the Tower of London (Freiburg Version, ToL-F; Kaller et al. 2012). In their study, participants were asked to watch MASC themed around peer and romantic relationships of four characters and were asked questions about their mental states, facial expressions, prosody, and content of their conversation. Their analysis revealed that set-shifting and planning abilities significantly explained variability in MASC, (WCST; Beta = .24, $p = .007$), but Go No-Go task (Beta = -.13, $p = .135$), or ToL-F (Beta = .04, $p = .656$) were not significant predictors in hierarchical analysis.

It is crucial to highlight that although the performance on the 2-Back and Task Switching explained unique variability on Strange Stories task, this does not evidence that Strange Stories is indeed a sensitive ToM measure given no significant group differences were observed between participants who self-disclosed being with or without ASD in our sample. Schuwerk et al. (2015) did not find substantial differences between neurotypical and ASD young adult participants on the Strange Stories task (p = 0.667). Consistent with our findings, Di Tella et al. (2020) also did not find a significant association between Strange Stories and inhibition (Tower of London) in their study of healthy young adults (19 to 27 years). However, Di Tella et al.'s (2020) findings were also inconclusive for the association between EF abilities of access (verbal fluency), updating (digit span backward), or shifting (Trail Making Test) and mental state Strange Stories task. Strange Stories in their study was associated with a non-verbal measure of cognitive abilities (standard progressive matrices). Dziobek et al.'s (2006) study participants with Asppergers's underwent videographed diagnostic interview, neurological, and radiological examination after being selected from specialty clinics. To maintain diagnostic rigor before conducting the study, a semi-structured questionnaire called the Autism Diagnostic Interview-Revised (ADI-R; Lord, Rutter, & Le Couteur, 1994) was further utilized to elicit collateral reports from their parents. The authors highlighted that compared to other ToM measures used in their study (Reading the Mind in the Eyes Test and basic emotion detection task), Strange Stories demonstrated low sensitivity in differentiating participants with and without Asperger's.

For the third hypothesis, we assessed if 2-Back and Task Switching would demonstrate additional prediction of TOMI-SR above and beyond demographic characteristics, participants' education, MH, ASD diagnosis, Go No-Go, and Visual Search task. Although no EF task explained variability on TOMI-SR, education, ASD, and MH conditions significantly contributed to each hierarchical regression model for this outcome variable.

Not many studies have explored the association between self-reported ToM and EF abilities. Crehan et al. (2020), in their study comparing clinically diagnosed ASD participants and neurotypical adults, found that individuals with limited ToM abilities as measured on TOMI-SR gave fewer looks during salient social information as observed on eye tracker during a social behavioral task. It's possible that the performance on the TOMI-SR did not rely on any EF mechanism explored in the present study since the elements of ToM tested in the TOMI-SR (understanding humor, consoling grieving people, initiating small talks) are so distinct from the cognitive demands of first and second-order ToM tasks. Perhaps incorporating social behavior measures using the eye tracking paradigm (see Crehan et al., 2020) could be better suited for explaining ratings on TOMI-SR than using EF abilities. TOMI-SR relies on comprehension of scenarios that sample social interpersonal behaviors to arrive at self-perceived ratings rather than attributing mental states to others–a cognitive component of ToM.

However, tools for measuring self-reported ASD symptoms (e.g., Autism-Spectrum Quotient) usually have questionable validity (Lundqvist & Lindner, 2017; Ruzich et al., 2015), and it is likely that TOMI-SR scores are affected by self-perceived deficits vs. actual functional social skills. Self-report measures introduce intrinsic response biases ranging from poor comprehension and misunderstanding instructions to social desirability. These biases are further compounded when self-report measures are used to assess cognitive constructs such as the self-reported capacity of attentional control, as people often underestimate or overestimate such abilities (Tang et al., 2020).

Contrary to our findings of better performance on self-reported ToM among individuals with self-reported mental health concerns, Zobel et al.'s (2010) study found compromised ToM abilities in individuals with chronic depression. However, other researchers have claimed that participants with high anxiety outperform those with low anxiety (e.g., Sutterby et al., 2012). Our contradictory findings from previous studies could be attributable to (1) methodological differences or (2) severity of mental health conditions.

TOMI-SR relies on the memory and comprehension abilities of the participants to read, recognize, and quantify their communication style and interpersonal behaviors. However, Zobel et al. (2010) utilized a cartoon picture story task in their study which may not have put the same cognitive demands on participants as TOMI-SR. Sutterby et al. (2012), on the other hand, used the RME (picture) task and a self-report measure, the Awareness of Social Inference Test. Besides RME, the investigators found significant group differences among women on self-reported ToM and anxiety scales. Their results could be attributable to reporting biases as empirical studies have consistently demonstrated that women over endorse and score significantly higher on self-attributed measures than men (Bornstein, 1995).

Regardless, diagnostic comorbidity is well-recognized in this population as individuals with ASD frequently meet the criteria for at least one other psychiatric disorder (e.g., Hutchins et al., 2021; Mosner et al., 2019; Rosen et al., 2018). We found a similar pattern as participants in the present study also reported being diagnosed with comorbid ADHD, eating, anxiety, depressive, and obsessive-compulsive disorders. Nevertheless, we did not include any diagnostic tool in the present study or obtain information on diagnostic severity from our participants.

Finally, we proposed that 2-Back and Task Switching would significantly explain the variability in Interpersonal Decentering after controlling for demographic, Go No-Go, and Visual Search variables. Only sex assigned at birth was the significant predictor of Interpersonal Decentering in the hierarchical model, but no other EF, demographic, or health history variables. Similar to our findings, Ahmed and Miller (2011), in their analysis of healthy participants between 18 and 27 years of age, found that gender was a significant predictor in explaining performance on the Faux Pas (narrative comprehension) task ($\beta = .34$, $p < .01$) where women significantly outperformed men on this measure. Comparable results were obtained from Müller et al.'s (2016) analysis, which found that gender significantly mediated performance on the Movie for the Assessment of Social Cognition performance task in a study of adolescents with and without ASD. Women with ASD have consistently shown less impaired performance on social cognitive measures compared to men with ASD (Baron-Cohen, 2002; Baron-Cohen et al., 2015; Muller et al., 2016), which supports that women have an advantage on tasks measuring ToM.

In the present study, Interpersonal Decentering number of interactions demonstrated an advantage for individuals without diagnosed or suspected ASD. Eurelings-Bontekoe et al. (2011) utilized TAT narratives to assess autistic information processing using two dimensions, Complexity of Representations of People and Understanding of Social Causality of the Social Cognition and Object Relation Scales (SCORS; Westen, 1985). The authors established that TAT narratives of individuals with autism were marked by a lack of core coherence, difficulty articulating and comprehending movements, and a tendency to leap to conclusions. Beaumont and Newcombe (2006) assessed 20 individuals with high functioning autism and 20 control volunteers on their performance on TAT stories and compared narrative coherence for mental state words, causal mental statements, and action causal statements. It was noted that individuals with high functioning autism employed fewer mental state causal statements than controls. These findings partially align with the participants' performance in our sample on the Interpersonal Decentering process scores (number of interactions), as participants with no ASD diagnosis had a higher number of interactions than individuals with suspected or diagnosed ASD. Our findings support the inference drawn from Eurelings-Bontekoe et al. (2011) study–individuals with ASD struggle to describe mentalizing processes in others and reach premature conclusions about their mental states.

From a process-focused approach and our obtained findings, it's reasonable to believe there is little or no association between EF tasks used in this study and Interpersonal Decentering. Most EF tasks begin with instructions, predetermined task demands, and a restricted response set. Interpersonal Decentering, on the contrary, taps into complex supramodal EF skills, i.e., it likely relies on brain regions that are implemented in abstract functioning for more than one sensory and EF resource such as language production, visual perception, along with working memory, planning, organizational skills, and cognitive flexibility. Additionally, these EF skills are expected to be kept online until the completion of the task. From that perspective, Interpersonal Decentering relies on higher-order executive processes than the implicit low-level executive functions the present study assessed.

Lastly, for our exploratory regression analyses with EF accuracy response times predicting performance on ToM tasks, only 2-Back match accuracy response time was significantly and positively associated with Interpersonal Decentering. This finding is partially comparable with the analyses conducted by Kalbe et al. (2010), who found significantly longer reaction times for cognitive ToM task than for affective ToM measure. Those authors attributed this difference to DLPFC and associated neural networks implicated in working memory, inhibition, maintenance of abstract rules in awareness, and cognitive empathy. In that regard, Interpersonal Decentering assesses the construct of ToM and the same latent EF skills as it permits participants to demonstrate initiation, planning (story details), and decision-making (character's role, plot, and conclusion of the story). Findings from the present study suggest that perspective-taking is a deliberate explicit process. Other TF tasks (Go No-Go, Task Switching) are likely implicit and provide automatic support. It is likely that the obtained levels in the present study, considering the ceiling effects, are necessary but not sufficient for mature Interpersonal Decentering performance. Nevertheless, methodological differences, rigorous control, and sensitive tools are needed to differentiate between internal arousal state and explicit behavioral expression latency.

Association Among ToM Tasks

False Belief task score was significantly and positively associated with Strange Stories performance. This association supports the claim that both of these tasks utilize a similar underlying domain of narrative comprehension related to cognitive processes of ToM and have a more significant shared task demand than other ToM tasks used in this study. False Belief and Strange Stories quantify or rather dichotomize the presence and absence of ToM as these tasks rely upon predetermined answer choices and limited performance variability inherent in a restricted range. Participants usually decide if a proposition is logical merely based on its phrasing rather than engaging in problem-solving or critical thinking abilities. On the other hand, Interpersonal Decentering uses fewer leading directions to relatively unstructured stimuli and focuses on the process-oriented approach of perspective taking (Bornstein, 2011), which is developmentally aligned with the cognitive demands expected in a social, interpersonal context.

However, besides first and second-order tasks being significantly associated, these tasks were not related to either Interpersonal Decentering or self-reported ToM. Our findings of a lack of association between different ToM tasks are comparable to previous who also found nonsignificant correlation between these tasks (Ahmed & Miller, 2011; Dziobek et al., 2006; Saltzman et al., 2000). The authors concluded that each ToM task likely examine separate component of social cognition.

Alternatively, a lack of association between first and second-order ToM tasks with TOMI-SR or Interpersonal Decentering suggests that they rely on distinct cognitive demands, possibly attributable to domain specificity captured through specific ToM measures. TOMI-SR outlines behavior samples of hypothetical social interpersonal circumstances where a participant is expected to rely on memory of past interpersonal encounters, comprehend the provided scenarios, identify and measure their communication style and interpersonal behaviors than discerning the mental states of others. By contrast, assessment of ToM as measured through Interpersonal Decentering has ecological validity as the less structured task demand of narrative production to pictured situations relies on initiative, abstraction, and planning abilities. Interpersonal Decentering stimuli were TAT images that depicted two or more characters. Strange Stories task, on the other hand, requires participants to understand the belief of only one character about the other. These differences underscore that social cognition is multidimensional and may not be adequately captured with one specific measure. Hence, our findings can be conceptualized from a multimethod multimodal assessment perspective (Hopwood & Bornstein, 2014) as the differing measurement method error variance could significantly explain their variability (see Factors Attributable to Intra-Individual and Inter-Task Variability section).

ToM and EF

In the present study, besides the Strange Stories task, EF abilities were not significantly associated with any other ToM measure. None of the EF variables accounted for a significant proportion of variance in False Belief, self-reported ToM, or Interpersonal Decentering. These results are comparable to those reported by Dziobek et al. (2006). In their comparative analysis of participants with Asperger's [*n* = 21 (19 men and two women), mean age = 41.6] and control group [*n* = 20 (18 men and two women), mean age 39.9], Dziobek et al. (2006) did not find a significant association between any of the ToM tasks (Strange Stories, Reading the Mind in the Eyes, video measure of complex ToM, self-reported empathy) and cognitive or EF abilities [IQ (WAIS verbal abilities and abstract reasoning), executive function (Stroop test, Verbal Fluency, and Trail Making Test), memory (WAIS digit span forward and backward, WMS Logical Memory and Visual Reproduction), attention (Digit Symbol Substitution Test), or visual processing (mental rotation and spatial visualization)].

In contrast to earlier findings (e.g., Vetter et al., 2013), this study did not observe a significant association between attention (Visual Search) and inhibition (Go No-Go) with any ToM task, irrespective of their complexity. As for inhibition, findings from Ahmed and Miller's (2011) study yielded similar results as inhibition was not associated with Strange Stories or Faux Pas task in their analysis of healthy adults. Studies on children and their social cognitive abilities have found inhibition to be a significant predictor of ToM. In the present study, Go No-Go and Visual Search had a ceiling effect. It is likely that inhibition plays an essential role in the early developmental stages of social cognitive processes but may only contribute as a prerequisite for acquiring and performing complex EF skills, which might explain lack of variability on such tasks (Ahmed & Miller, 2011). In other words, certain EF abilities are crucial for developing ToM but not so much for ToM cognitive processes once they are matured.

This study's findings can be compared to the conclusions drawn from Schuwerk et al.'s (2015) study that evaluated implicit and explicit theory of mind processes in neurotypical adults and individuals with ASD (mean age 24.1). The performance of participants with ASD indicated a lack of spontaneous sensitivity towards another's mental state on the eye-tracking version of the false belief (implicit ToM) compared to neurotypical adults. However, and similar to our results, no significant difference was observed between individuals with ASD and neurotypical participants on the Strange Story task. The authors concluded that the implicit system is crucial for spontaneous sensitivity in differentiating belief states in others, while explicit processes support the overt expression of mental state understanding.

Given the assumptions mentioned above, the present study's findings can be interpreted from Apperly and Butterfill's (2009) two-systems framework of implicit and explicit processes (Bornstein, 2011; Frith & Frith, 2008; Keysers & Gazzola, 2007; Weinberger & McClelland, 1990; Schaafsma et al., 2015). High-level cognitive and executive processes are more taxing and sustained by low-level functions. This was evident as high error rate was noted in 2-Back task (see Table 5) compared to Visual Search and Go-Go task. As such, implicit social perceptual processes are automatic, reflex-like, and quick in picking clues in the context of understanding mental representations (e.g., Clements & Perner, 1994; Southgate et al., 2007).

The signs of executive dysfunction are difficult to quantify as individuals can exhibit intact functioning in specific domains and struggle in others. For example, a person can have unimpaired initiation and focus yet they can struggle to shift their focus or have poor planning abilities. According to Hart et al. (1999), the fundamental components of EF include (1) establishing a purpose or end goal to guide behavior, (2) chronological organization of the sequence of events to meet end goals, and (3) the adaptability of thought processes, i.e., the tendency to shift focus and adapt to achieve a goal.

Related to Hart et al.'s (1999) assumptions, complex ToM tasks, for instance Interpersonal Decentering, rely on purposeful goal directed behavior. Despite apparently intact core cognitive capabilities, memory functioning, and language ability, people display comparable challenges in "real world" circumstances. As such, participants can perform adequately on various concrete EF tasks due to their inherent structure and performance predictability yet struggle in social interactions or demonstrate poor social cognitive maturity on complex ToM tasks.

Most studies that have found significant associations between EF and ToM abilities have observed implicit EF processes and associated activated brain regions (e.g., Cascio et al., 2022; Saxe & Powell, 2006; Schurz et al., 2015). This assumption can be corroborated by a recent fMRI study by Cascio and colleagues (2022) among late adolescents who found that *NOT* the inhibition task performance, but the associated brain region activation was associated with significant demographic variables of the study. This study attests that findings can lead to misleading conclusions if methodological inconsistencies across studies are not critically scrutinized (see Factors Attributable to Intra-Individual and Inter-Task Variability section below). Nevertheless, these are only theoretical assumptions for our findings and warrant further investigation with more sensitive and ecologically valid methods.

Gender Differences

As mentioned above, significant gender differences were observed in Interpersonal Decentering as women demonstrated mature perspective-taking abilities. Our findings corroborate previous findings on the TAT task that found significant gender differences (Jenkins et al., 2020; Jenkins et al., 2022). One possible reason for the substantial gender results is that the TAT narratives rely on a process-focused method rather than self-report assessments of social cognitive components in college student samples. Implicit Decentering responses, as measured by TAT accounts, highlight distinct elements of participants' performance different from those of self-report measures, which are self-attributed in nature (McClelland, Koestner & Weinberger, 1989; Weinberger & McClelland, 1990). Implicit responses sample spontaneous processes seen in various social contexts and interpersonal settings. On the other, self-attributed responses are often self-perceived assumptions and situationally dependent, indicating that the participant is aware of the task demand and situational requirements (Bornstein, 2002).

Gender differences on ToM tasks have been frequently observed in empirical studies (e.g., Flannery & Smith, 2017; Olweus & Endresen, 1998). Regarding Interpersonal Decentering, it should be noted that some distinctions can be drawn between an individual's capacity for perspective-taking and their tendency to effectively utilize this skill in interpersonal interactions (Jenkins et al., 2013; Smith & Rose, 2011). A person can have an intact ability for perspective-taking, but they may not be motivated to intentionally engage in mature perspective in every social, interpersonal exchange due to its taxing nature as discussed above. For instance, Flannery and Smith (2017) found that girls (ages 12-17) performed significantly higher than boys on a social perspective-taking task of hypothetical vignette assessments. However, the authors concluded that lower performance in boys on social perspective-taking task was not associated with a lack of perspective-taking ability but with stereotypical gendered beliefs and social expectations. Nevertheless, some inconsistencies are noted regarding gender differences in mentalizing abilities (Derntl et al., 2010; Ragsdale & Foley, 2011; Wakabayashi & Katsumata, 2011).

ToM and Language

All the ToM tasks in the present study relied on narrative comprehension (False Belief, Strange Stories, TOMI-SR) and linguistic abilities relevant to narrative production (Interpersonal Decentering). Besides the 2-Back task and Task Switching, English fluency accounted for significant variability in the Strange Stories performance. Comparing the findings with those of other similar studies confirms the substantial contribution of verbal abilities in explaining performance on ToM measures, except for Interpersonal Decentering, used in this study. For instance, Ahmed and Miller (2011) found a positive association between D-KEFS Verbal Fluency test and the Strange Stories task. Providing a unique perspective on the similar findings as to the present study, Dziobek et al. (2006) concluded that Strange Stories is confounded by comprehension abilities and may not validly measure mentalizing ability as this was the only ToM task that showed a positive association with verbal IQ.

A significant positive relation between social cognition and language ability has been extensively documented (Annotti & Teglasi, 2017; Botting, 2002; Cutting & Dunn, 1999; Hildebrandt et al., 2015; Milligan et al., 2007; Norbury & Bishop, 2003) as language abilities mediate the adaptive execution of ToM. Compared to bilingual English speakers, monolingual or English-dominant bilingual speakers may have more developed lexicons that underpin understanding of ToM activities which is *NOT* equivalent to underdeveloped ToM abilities among bilinguals. Conversely, previous research has demonstrated that bilingualism is advantageous to ToM (Navarro & Conway, 2021). However, it should be noted that the positive association between bilingualism and ToM tasks could be task-dependent and less relevant for studies that have utilized pictorial rather than verbal ToM tasks such as the Sally-Anne task (Rubio-Fernandez & Glucksberg, 2012), Director task (Dumontheil, Apperly, & Blakemore, 2010; Navarro & Conway, 2021), or False Belief task (Diaz & Farrar, 2018). The present findings suggest that English fluency significantly contributes to performance on Strange Stories. However, this conclusion is speculative since we did not include any verbal ability measure to account for language variability in our analysis.

Bivariate Association with Demographic Variables

In the present study, the number of siblings in the household was significantly but negatively associated with the Strange Stories performance. The negative association between having more siblings and ToM abilities contrasts with McAlister and Peterson's (2007) longitudinal study of children between ages 3 to 9 years, which found that having two or more child-aged siblings, compared to infant or adult siblings, was associated with higher ToM. Surprisingly, most studies on sibling relationships and their influence on ToM development are conducted on young children (e.g., McAlister & Peterson, 2006, 2007, 2013; Song & Volling; 2018). Perhaps children having frequent conversations with siblings and parents about thinking and feelings create social interactions that encourage a child's ToM development. More importantly, developmentally close siblings facilitate ToM development by engaging in activities that nurture social cognitive processes such as arguments, negotiation, sympathy, jokes, and teasing. However, the same conclusions cannot be drawn for emerging adults as collaborative activities switch from siblings to peers and romantic partners.

Although the finding of a negative association between number of siblings and ToM in the present study is inconsistent with previous studies with children, a few studies with young adults have identified transitionary struggles of emerging adulthood, child-parent relationship, and social comparison between siblings that can negatively impact their social adjustment (Hamwey & Whiteman, 2021; Rauer & Volling, 2007). Hamwey and Whiteman (2021) utilized the measures of social comparison and basic empathy among young adults (ages between 18 and 28 years). The authors found that social comparisons between siblings were associated with sibling jealousy, which also explained depressive symptoms and sibling conflict. From the authors' perspective, it's possible that resentment among siblings mediates the associations among cognitive processes, interpersonal adjustment indicators, and relational dynamics. It should be noted that the data for the present study were collected during the COVID-19 pandemic, which might serve as an underlying mediating factor for this negative association.

Recent studies have identified family instability and uncertainty during the COVID-19 crisis significantly and negatively impacted family relationship quality (e.g., Cassinat et al., 2021; Perkins, Rai, & Grossman, 2021). Moreover, the number of siblings was significantly but negatively associated with SES in this sample (discussed later). These findings should be interpreted with caution as they may be related to cohort effects in general.

Significant associations were observed between SES and Interpersonal Decentering average number of interactions. SES also significantly differed across ethnic groups (Asian Americans > European Americans > African Americans> Latino American/Hispanic) in this sample. Although there is compelling evidence that EF is positively linked with socioeconomic status (Fatima et al., 2016; Theodoraki et al., 2020), only a few studies have explored the association between SES and ToM processes. Pluck et al.'s (2021) study among adolescents (12 to 17 years) found that SES was significantly associated with ethnicity, EF abilities (motor planning, Tower; time per move ratio), and ToM performance (RME and Faux Pas). However, neither EF nor ToM abilities differed with age when the investigators controlled for age and vocabulary. The authors concluded a significant moderating influence of language and verbal skills explained the association between SES, EF, and ToM. Noble et al.'s (2015) study also identified the influence of SES, parental education, and ethnicity on cortical regions associated with reading and language abilities, executive functioning, and spatial skills, and found a significant contribution of psychosocial factors in a large sample of 1099 participants (3 to 20 years of age).

Gender identity, age, and education were significantly correlated with the 2-Back task in the present study. Our findings contradict Schmidt et al.'s (2009) study that did not find significant gender differences in their fMRI study. The authors concluded that men and women perform equally well and use similar brain regions while performing the working memory task. Partially relevant to this study's findings, Morais et al. (2018) found that age and education were significantly and positively associated with better performance on central executive tasks (digit span backward and reading span) in a sample of healthy adults aged 18 and 65.

The presence of MH diagnosis in the present study was significantly associated with the Visual Search task, as participants with no self-disclosed MH diagnosis performed better than those with diagnosed MH conditions. Similarly, participants with no MH diagnosis demonstrated better performance on Task Switching than those with diagnosed MH disorder. Although these group differences were not planned comparison and were noted post hoc, the present findings are comparable to previous studies that noted slower cognitive tempo (e.g., Meiran et al., 2011) and impaired task switching (e.g., Sabb et al., 2018), more complicated attentive search strategy (Hammar et al., 2003; Hammers & Weisenbach; 2020) in clinical samples compared to healthy participants.

Factors Attributable to Intra-Individual and Inter-Task Variability

The present study employed a multimethod multimodal approach to understanding intra-individual and inter-task variability by complementing self-report measures, commonly used performance-based tasks of EF functioning, and less structured process-oriented Interpersonal Decentering (see also Bornstein, 2011). This approach was utilized partly to assess differential performance inherent in measurement methods of traditionally validated measures and investigate differential performance in ToM tasks, presumably measuring a domain-specific construct of ToM. There are a few, albeit significant, factors to take into account while interpreting the findings of studies utilizing EF and ToM tasks, as considerable differences in stimulus types exist.

In a comprehensive review of process-focused psychological assessment methods, Bornstein (2011) asserted that the availability of well-validated evaluation tools does not imply scientific rigor or unbiased decision-making. Most of the EF tasks (with few exceptions; see Appendices B-H) usually used to assess neurocognitive functioning are narrow in focus. The assessment of EF in controlled conditions limits their generalizability and thus renders their ecological validity questionable. For instance, when tasks presumably measuring initiation, planning, cognitive flexibility, and decision-making are assessed using a predetermined structure and response format, there's little room for variability or "executive demands" as would be expected in real-world situations.

Baggetta and Alexander (2016), in their comprehensive systematic review, highlighted that studies on EF abilities utilized approximately 109 distinct tasks to measure executive processes, out of which 53 tasks were used repeatedly. In the present study, inhibition and attention were assessed through the visual modality and may not be as challenging as inhibitory and attentional demands needed in social and interpersonal circumstances. For example, individuals are expected to inhibit their assumptions and verbalizations about the speaker to understand what is being stated in a given context. Perhaps the tasks used in this study did not reach the complexity threshold expected for social cognitive processes in adults. Alternatively, it is possible that various tests share a general attentional ability (Bull et al., 2008; McKinnon & Moscovitch, 2007) and may not demonstrate much variability. Whereas all the EF tasks in our study relied on visual attention and no task depended on auditory modality (a significant strength), Kidd and Humes (2015) employed an auditory N-Back task to assess the recall accuracy of the spoken words and sentences. Contrary to our findings of no association between ToM and inhibition, Vetter et al. (2013) found a significant association between these two cognitive processes when they utilized the anti-cascade task to measure inhibition. Hence, a lack of association between attention and inhibition with measures of ToM could likely be associated with task complexity and modality.

Significant for EF tasks, factors like inter-stimulus interval (ISI) likely impact performance (Kuiper et al., 2016). For example, ISI considerably differed between the Go No-GO task versus the Visual Search and the Task Switching trials. The Go No-Go task had smaller ISIs than the other tasks. Finally, it is worth noting on any given EF task whether the errors are followed by corrective feedback or not. For instance, although Task Switching is expected to be a considerably complex task as it depends on attention, working memory, and cognitive flexibility (participants were expected to remember which key to press when they see an even or odd number, vowel or consonant, and which corner of the square), participants saw a reminder screen after every error which did not happen for any other task in this study. These factors may have impacted the variability estimates between different tasks in this research. Needless to say that more extensive investigation in both clinical and non-clinical populations is warranted using a comprehensive battery of EF tasks and ToM measures to demonstrate social cognitive processes and executive skills associations.

Several tasks in the present study had ceiling effects. Performance on False Belief and Strange Stories suffer from restricted scoring ranges (False Belief item scored either ‘0’ or a ‘1’ and Strange Stories scored on ‘0’, ‘1’, or ‘2’). As noted, this factor substantially impacted drawing statistical conclusions, comparing performance with other ToM tasks (Interpersonal Decentering and TOMI-SR), probably underestimating effect sizes and validity coefficients of relationships between EF and ToM variability that might appear in other younger population.

In the social cognitive context, first and second-order ToM tasks depend on linear mentalizing processes, language skills, memory, and visual perception more than does complex social cognitive ability. Additionally, dissimilarities inherent in task characteristics could have contributed to our findings. Due to the diversity in definitions, theoretical assumptions and conceptualizations, and varied measurement methods, executive functioning remains a complex construct to be validly studied. Particularly problematic is the fact that correlation sizes between EF and ToM are influenced by the reliability of the tests utilized, and many commonly used EF or ToM tasks appear to have poor test-retest reliability (Bishop & Norbury, 2002; Norbury & Bishop, 2003; Pluck et al., 2019). In contrast to EF tasks that provided participants with explicit instructions, practice items, and expectations to perform a structured task (press specific buttons on a keyboard), Interpersonal Decentering stories stimuli (TAT cards) used open-ended instructions to generate spontaneous narratives. Lezak (1995) noted that a narrative production task provides an opportunity to infer patients' ability to deliver goal-directed ideas and maintain cohesive thoughts. It is a common practice for studies to combine different measures and form a composite score for ToM (Bernstein et at., 2017; Fahie & Symons, 2003; Saltzman et al., 2000; Yirmiya et al., 1998). This study showed that this method might not be the most effective for identifying task-specific performance domains as each commonly used ToM task relies on separate underlying components (e.g., verbal, comprehension, visual recognition, auditory, simultaneous processing, etc.).

Furthermore, using self-report measures to explore perspective-taking might result in social desirability biases, making them less generalizable to interpersonal interaction situations (Annotti & Teglasi, 2017). Psychologists frequently consider evidence drawn from self-report validity scores as the true representation of the presence or absence of actual behavior when several factors such as context and evaluation setting, differences in respondents (e.g., self-referred or mandated), or the stated or implied purpose of evaluation (e.g., child custody or disability benefits) produces differential outcomes (Bornstein, 2011). The participant must simply follow instructions of self-report measure and respond to questions with known correct answers or socially and contextually desirable responses.

Additionally, self-report measures have the potential to introduce social desirability biases in responding, which leads to self-perceived, often inaccurate, self-appraisal since individuals inadvertently provide more expected than truthful proximations of their social cognitive processes. The use of explicit instructions in self-report measures limits the responder's ability to provide circumstantial thought processes that may emerge during an interpersonal interaction as they pertain to complex mentalizing processes unique to each situation where such social exchange unfolds. As a result, these methodological limitations likely render self-report measures less generalizable to real-world circumstances than narrative techniques (Teglasi et al., 2022). Findings from previous studies (Ahmed &Miller, 2011; Dziobek et al., 2006) drew similar conclusions as this study and suggested that inter-task variability, whether between ToM measures or EF abilities, can significantly impact the findings and yield inconsistent results.

Strengths

There were numerous notable strengths of the current study. While there is growing interest in the relationship between executive control and mentalizing, little subclinical research has been undertaken. The present study addressed this gap in the research by investigating the relationship between ToM and executive processes in a sample of typically developing individuals. This study highlights that ToM and EF abilities are interrelated yet complex phenomena. The findings extend previous work by exploring whether: (1) ToM is linked with EF abilities; (2) there is cognitive demand variability among different measures of ToM; (3) a ToM task significantly associated with EF skills may not necessarily be a better measure than other ToM tasks; and (4) EF tasks and methodology sensitivity play a crucial role for drawing causal links between EF and ToM. Our findings also show that, although various measures of executive control have some variation, they capture distinct features of higher-order processing. However, more sensitive EF measures may be needed in future studies to capture and explain the complexity of ToM that are ecologically valid, and specifically provide appropriate age ranges to capture developmentally appropriate performance. This study has implications for the clinical population, particularly individuals with self-recognized atypical cognitive and behavioral symptoms of perspective-taking deficits.

To the best of our knowledge, this was the first study that compared narrative comprehension tasks with a narrative production task. The present study utilized TAT narratives to sample complex social information processing dynamics to explore ToM complexity within a typically developed young adult sample and the commonly used theory of mind tasks to differentiate between the executive and interpersonal perspective-taking processes. Furthermore, a self-report measure for complex ToM was also included to obtain a comprehensive perspective on social cognitive abilities. Traditional measures of ToM rely on standardized tasks (e.g., the Sally-Anne Task, False Belief, Mind in the Eye), which have major drawbacks that include poor dynamic variability from one condition to another, questionable criterion validity, poor test-retest reliability, and the existence of ceiling effects when less complex mentalizing abilities are implicitly mastered despite functional deficits. This study underscores that first and second-order ToM tasks are not well suited for young adults as these tasks inadequately capture performance variability observed in clinical or non-clinical samples. This restricts the ability to draw inferences and limits the capability to understand the full potential of ToM among adults. This study can be regarded as an exploratory endeavor rather than a confirmatory analysis. Despite several limitations, critical questions are raised regarding EF abilities and sensitivity of commonly used ToM tasks. Future studies can extend these findings by treating them as testable hypotheses rather than assertions.

Limitations and Future Directions

Several challenges in conducting the present study warrant attention. This study is correlational and exploratory at best and makes no mention of the directionality of the relationship between ToM and executive processes. Thus, the degree to which executive dysfunction might explain challenges in mentalizing capacity is unknown and deserves more exploration in future studies.

The inconsistent pattern of findings should be interpreted in the context of the evaluation methodologies used. EF tasks utilized in this study are usually better suited for experimental designs, repeated measure designs, or comparative studies, which have their merits for specific purposes (e.g., to study brain regions associated with specific EF abilities, neurological processes, TBI, etc.). However, such tasks have limited ecological utility, especially when used in a single sample design with less severe medical conditions. Future studies can incorporate more complex EF tasks for assessing abilities such as problem-solving, sequential thinking and deductive reasoning, self-control, self-monitoring, planning and prioritizing, and emotional recognition. These everyday cognitive demands contribute more to interpersonal understanding than the basic EF abilities assessed in this study. It is reasonable to say that the present study's behavioral techniques are not well suited to detect executive functioning variability in TOMI-SR or Interpersonal Decentering in a college student sample.

Despite treating gender differences as a covariate, the pattern of findings found in the present research may be more female-specific and restricted in its generalizability to male samples. The present study's data was gathered by convenience sampling among undergraduate college students and social media announcements which may limit the generalizability of the results to a broader population. Because most of the participants in this research were cisgender women, our sample had a large gender imbalance. This is due to the fact that most students in psychology courses are recruited from the university population, which has a clear participation bias.

Data were collected online during the COVID-19 pandemic, and context-based factors such as mood, cognitive load, and emotional processes could have impacted their performance. Given that participants were in their home environment, participant situational characteristics could not be controlled, e.g., distraction at home, pets, surrounding noise, people walking in, and inconsistent internet connection (although no participant dropped out from Zoom in the middle of the study). At the study's conclusion, some participants reported that they could not see the EF task due to the website pop-up blocker despite the researcher asking and confirming if their pop-up blocker was disabled before providing them with the study link. Since they took the EF after completing all the self-report measures, fatigue may have contributed to their variable performance. Hence, variable test-taking conditions introduced substantial error variance in their performance.

We found significant group differences between monolingual and bilingual speakers on Strange Stories task. Although it was assumed that the verbal abilities of bilinguals and monolinguals were equivalent, given they were university students, it is conceivable that there were differences that were not considered in this research, which would undermine the findings. For example, we only asked if participants were monolingual or bilingual English speakers and did not control for language variability as both English dominant and English as a second language (ESL) marked themselves as bilinguals. Kremin and Byers-Heinlein (2021) warned against discretely categorizing monolinguals and bilinguals as the authors claimed bilingualism is complex to define. Previous studies have utilized IQ measures and verbal ability indices (e.g., Ahmed & Miller, 2011, Gökçen et al., 2016). Perhaps adding a measure of cognitive abilities can further differentiate and explain whether the obtained results are a function of EF abilities or cognitive skills (verbal comprehension, perceptual reasoning) or both by controlling their variability.

The present study did not incorporate response time with any of the ToM task. Hence, it is uncertain whether the obtained performance differences between task was related to the social cognitive complexity or the story length. Since False Belief, Strange Stories, TOMI-SR, and Interpersonal Decentering rely on language abilities, future studies can incorporate each vignette's story's length for controlling comprehension complexity as a function of story length.

Although the present study asked several demographic questions regarding mental health, use of medication, and preexisting neurodevelopmental condition (a significant strength), we did not exclude or match the participants for their history variables. Although group differences across outcome variables were noted for ASD and MH diagnoses, these comparisons were self-reported, post hoc, and were not anticipated when conceiving this study. Hence, the scope of the present study was limited due to it being a single sample design. Furthermore, diagnostic comorbidity among individuals with ASD was also noted in our sample, especially secondary diagnoses of anxiety and depressive disorders and multiple conditions in some participants.

Finally, the present study found no significant findings on Interpersonal Decentering, which is likely attributable to the small sample size and preexisting neurodevelopmental and mental health conditions in our participants. Future studies can conduct comparative analyses by obtaining data from a larger sample to explore social-cognitive variability across control, ASD, and MH groups to determine if a true effect exists on Interpersonal Decentering. Therefore, controlling for demographic and mental health variability in the participant pool could be especially important when studying ToM and executive function abilities. These characteristics can affect task performance and complicate accurate profiling of social cognitive processes associated with ToM variability in the clinical and general population.

Conclusion

The present study provides insight into the relationship between executive abilities and social cognitive maturity among adults and demonstrates that these abilities are intricately related yet distinct phenomena. Findings largely support that although several executive processes are involved in perspective taking, cognitive demand heterogeneity across various measures of theory of mind may differentially relate to such abilities. Although not specifically investigated in this study, it is crucial to consider that interpersonal interactions require parallel processing of several higher-order executive demands. A person can demonstrate intact performance on individually devised tasks but may continue to experience difficulties in social and interpersonal contexts. The present findings suggest that we can gain further insights into the complex phenomenon of perspective-taking from process-oriented research methodologies.

APPENDIX A

COMMONLY USED TOM TASKS

No	Measure	Type	Description
1.	Reflective Functioning Questionnaire (RFQ; Fonagy et al., 2016)	SR	Self-report measure comprising 8 items divided across two subscales: certainty and uncertainty about mental states. Participants are asked to mark their responses on a 7-point rating scale ranging from strongly disagree to strongly agree.
2.	Interpersonal Reactivity Index (IRI; Davis, 1980, 1983b)	SR	Self-report measure designed to assess both cognitive and affective (emotional) constructs of empathy. The four subscales are: Fantasy, Perspective-Taking, Empathic Concern, and Personal Distress 7 items each.
3.	Theory of Mind Inventory-Second Edition, Self-Report (ToMI-2-SR-A; Hutchins et al. 2012)	SR	60-item Self-report inventory designed to assess self-perception regarding affective empathy, metaphor, episodic memory, hypocrisy, social common sense on a continuum and hash mark response arrangement.
4.	Reflective Functional scale (RFS; Taubner et al., 2013)	IBR	Assess metalizing ability from AAI transcripts and assesses individual differences in the participants' ability to mentalize attachment relationship using 11-point scale ranging from antireflective to exceptionally reflective/
5.	Theory of Mind Assessment Scale (Th.o.m.a.s; Bosco, Gabbatore, Tirassa, & Testa, 2016)	IBR	Semi-structured interview for adolescents and adults. Contains 4 subscales measuring first-order and second order belief, egocentrism and other belief state.
6.	Metacognition Assessment Interview (MAI; Semerari et al., 2012)	NP, IRB	Semi-structured interview evaluating mental states in the self and others. Participants are asked to narrate autobiographical memory from the previous six months. An interviewer than asks questions about Self and Other domain comprising of two sub-functions of monitoring, integrating, differentiation and decentration, and assigns a score from 1 to 5 to each response.
7.	Reading the Mind in the Eyes task (RME; Baron-Cohen et al., 2001a)	ER	Participants see photographs of eye region, and are asked to select from the provided glossary of words what the person in the photograph thinking or feeling
8.	Ekman-60 Faces Test (Ekman & Friesen, 1976)	ER	Uses a range of 60 photographs of facial affects of 10 actors. Each actor displays 6 basic emotion (happiness, sadness, disgust, fear, surprise and anger). Participants are asked to recognize facial expressions and earn a point for each correct response.
9.	False Belief Task (Wimmer & Perner, 1983)	SC	Fictional story has two characters, Sally and Anne. Sally puts marbles in the basket and goes on a walk. Ann takes the marbles and put them in a box. Participants are asked where Sally would search for the marbles after she comes back from her walk.
10.	Faux pas Test (Baron-Cohen, O'Riordan, Stone, Jones, & Plaisted, 1999)	SC	Consists of situations with negative consequences. Participants are told situations where a speaker says something without considering if the listener might not want to hear or know. It detects participants' ability to detect inappropriateness, intentions and beliefs.
11.	The Awareness of Social Inference Test (TASIT; McDonald, Flanagan,	SC,ER	Comprised of three parts; emotion evaluation test, test of social inference minimal and test of social inference enriched. Emotion evaluation tasks are video-based vignettes

No	Measure	Type	Description
	Rollins, & Kinch, 2003)		representing 7 basic emotions. Social inference task consists of paradoxical, sarcastic scripts and comprehension tasks. Social inference enriched incorporates contextual-non-verbal cues and comprehension.
12.	Florida Affect Battery (FAB; Bowers et al., 1998)	ER	Assesses the perception of facial and prosodic affect and includes 10 different subtests of facial affect tasks, prosody tasks, and cross modal facial-prosody tasks.
13.	Emotion Recognition Task (ERT) & Emotional Bias Task (EBT; Robbins et al., 1994, 1998)	ER	ERT: Computer-generated images are displayed to the participants for 200ms depicting facial features of real individuals. Participants are asked to select the emotion displayed after each image is covered. EBT: Displayed images morph between two emotions (Sad to happy) and displayed for 150 ms, after which participants are asked to select only one emotion of the two alternative forced choice.
14.	Strange Stories Test Happé, 1994; White et al., 2009)	SC	Participants are asked to read written stories and demonstrate comprehension of underlying mental states of the story's characters ranging from joke, lie, misunderstanding, sarcasm, irony, contrary emotions and the like.
15.	Role Taking Task (RTT; Feffer, 1959, 1970)	NP	Assessed an individual's ability to take more than one person's perspective simultaneously. Participants are required to create stories about a picture showing two or more characters. Subsequently, they are then asked to recreate the stories from the perspective of each individual depicted in the picture.
16.	Thematic Apperception Test (TAT) Interpersonal Decentering (Feffer et al., 2008; Jenkins, 2008; Murray, 1943;)	NP	Participants narrate stories based on what characters are thinking, feeling, what happened in the past, what is currently happening, and what will happen in the future. Provided narratives are then scored on for nine levels of increasingly complex interpersonal decentering activity.

SR: Self-Report Measures; IBR: Interview-Based Ratings; NP: Narrative Production Task; ER: Emotion Recognition Task

APPENDIX B

EF TASKS

Table B.1

Commonly Used Attention Tasks and Their Brief Description

No.	Attention Tasks	Brief Description
1	*Forwards Digit Span	Participants are required to repeat the digit sequence in the same order as it is given. This test measures auditory attention
3	*Symbol Span	Participants briefly see a sequence of abstract symbols and select the symbols in the same order among distractors. This task measures focused selective visual attention.
4	*Coding	Participants copy the symbol that goes along with each specified number in a limited time. This test measures selective visual attention.
	*Symbol Search and Cancellation	Participants are required to search and cancel target symbols among distractors. These tasks measure selective attention under time constraints.
5	Conner's Continuous Performance Test (CPT; Conners & MHS Staff, 2000)	Participants view random letters on their screen. They are required to press the key every time they see a letter except for "x." This task measures continuous and selective attention (visual and auditory), along with inhibitory function and impulsivity.
6	Test of Variable Attention (T.O.V.A; Greenberg, et al., 2018)	Like CPT, this task also measures continuous and selective attention, along with inhibitory function and impulsivity
7	Paced Auditory Serial Addition Task (Gronwall, 1977; Gronwall & Sampson, 1974)	Participants listen to a list of 60 pairs of randomized digits, and add each digit immediately to the one preceding it. This test measures divided and sustained attention.
8	Digit Vigilance Test (Lewis & Rennick, I 979)	This test measures sustained visual attention. Participants are required to cross out 6s and 9s among distractors as quickly as possible in a limited time.
9	Trail Making Test (Reitan, 1955)	Participants are required to attentively connect encircled numbers (Trail Making A) and numbers and letters (Trial Making B) arranged randomly on a sheet of paper. This task measures selective and divided attention
10	Ruff 2 & 7 Test (Ruff & Allen, 1996).	Participants are asked to mark only 2s and 7s among distractors for 5 minutes. This task measures sustained and selective visual attention.

*WAIS-IV (Wechsler, 2008); WMS-IV (Wechsler, 2009).

Table B.2

Commonly Used Inhibitory Tasks and Their Brief Description

No.	Inhibitory Tasks	Brief Description
1	Stroop Task (MacLeod, 1991)	Incongruent stimuli are provided. Color names (e.g., blue) are written in different color ink (e.g., red). Participants are required to ignore the written color's name and instead attend and report the color of the ink (also provides reaction time comparison between trials).
2	Simon task (Hommel, 2011)	Participants are instructed to press on the left when presented with Stimulus A and press on the right for Stimulus B. Only one stimulus is presented at a time, which can either appear on the right or the left. Incongruent side orientation (spatial incompatibility, or stimulus-response) compatibility is experienced when participants are required to press left when stimuli appear on the right which slows down their response time. The assumption is that humans have a prepotent tendency to respond on the same side as stimuli (Hommel, 2011; Lu & Proctor, 1995).
3	Flanker task (Eriksen & Eriksen, 1974; Mullane et al., 2009)	Participants are instructed to selectively attend to the stimuli presented in the center of the screen and ignore the surrounding stimuli, "flanking stimuli." The assumption is that participants struggle to inhibit the irrelevant stimuli as this task assesses the ability to suppress the response inappropriate for that particular trial.
4	Antisaccade task (Munoz & Everling, 2004)	Participants are required to make saccadic eye movement away from the target. This task measures voluntary, flexible control of movements. Responses to anti-saccades have longer reaction times (latency) and participants make more errors during antisaccade trials. The task relies on top-down suppression of a reflexive automatic saccade.
5	Go/no-go tasks (Cragg & Nation, 2008)	This task assesses inhibitory control and requires participants to respond to a specific stimulus when it appears on the screen (go) or "no-go" if you see anything else other than the target on the screen.
6	Stop-signal tasks (Verbruggen & Logan, 2008)	Participants are required to respond as quickly as they can to a predetermined stimulus. This task puts participants in a state of preparedness, but as they are ready to respond, a stop signal is displayed to inhibit their response on that particular trial.
7	Trails Making Test B (Reitan, 1955)	The test required participants to connect encircled numbers and letters arranged randomly in an alternative pattern (from number to letter and so forth) chronologically (Trail B). The test is designed to measure attention, speed, and inhibition of a prepotent response (a tendency to continue connecting only numbers or only letters).

Table B.3

Commonly used Working Memory Tasks and Their Brief Description

No.	Working Memory Tasks	Brief Description
1	Trail Making Test (Reitan,1955)	The test requires participants to connect encircled numbers and letters arranged randomly in an alternative pattern (from number to letter and so forth) chronologically (Trail B). The test is designed to measure attention, speed, and inhibition of a prepotent response (a tendency to continue connecting only numbers or only letters). This test also measures attention and processing speed.
2	*Backward Digit Span	Participants are given a list of number and they are required to repeat back the numbers in the reversed order.
3	*Letter-Number sequencing (verbal)	Random letters and numbers are provided to the participants. They are required to arrange letters first in the chronological order first and then the numbers in the chronological order.
4	*Arithmetic	Participants solve word problems in a limited amount of time without using paper and pencil.
5	*Visual working memory (spatial addition, symbol span)	Participants observe sequential placement of blue and red circles on a grid, after which they are asked to add or subtract circle locations based on predetermined rule (spatial addition). Participants see a series of abstract symbols after which they are asked to select symbols from a collection of symbols in the same order they saw in the initial trial (symbol span).
6	Corsi Block Test (Corsi, 1972; Lezak, 1995).	Participant is required to observe the examiner touch a series of blocks, and then touch the blocks in the same order as the examiner
7	Adaptive Composite Complex Span (Gonthier et al., 2016)	A test battery that consists of visuospatial (symmetry span), mathematical (operation span) and verbal (reading span) subtests.
8	Consonant Trigram Task (Peterson & Peterson, 1959). Also called Auditory Consonant Trigrams (Mitrushina et al., 2005)	Participants are required to hold consonant trigrams (e.g., E, L, K) in mind while they count backwards from 100 by 3s (or any other number) until they are asked to stop and recall the letters.
9	Paced Auditory Serial Addition Test (Gronwall, 1977; Gronwall & Sampson, 1974)	Participants listen to a list of 60 randomized digits and add each digit immediately to the one preceding it (e.g., 3, 5...’8’, 2…’7’,4…’6’ and so on).
10	Alpha Span (Craik, 1990)	Participants listen to a list of unrelated words (incremental difficulty from two to eight words) and recall word in alphabetical order.
11	Self-Ordered Pointing task (Petrides et al., 1993;	This task measures spatial working memory. A set of 12 pictures are shown to the participants ad they are asked to pick one image. Pictures are then scrambled on the next screen, and they are instructed to pick a

No.	Working Memory Tasks	Brief Description
	Ross, Hanouskova, Giarla, Calhoun, & Tucker, 2007).	different image. The stimuli are repeated, and errors are recorded when participant picks a previously selected image.
12	N-back task (Jaeggi, Buschkuehl, Perrig, & Meier, 2010).	Participants are presented a sequence of stimuli on a screen one after another, and they are asked to respond if the current stimuli are the same as they saw N trials ago. N can be any number between 1, 2, 3 trials ago, etc. Higher N increases the complexity, along with rate of stimuli presentation, and the size of stimuli set.

* (WAIS-IV, WMS-III; Wechsler, 1997)

Table B.4

Commonly used Cognitive Flexibility Tasks and Their Brief Description

No.	Commonly used Cognitive Flexibility Tasks	Brief Description
1	WCST (Heaton, Chelune, Talley, Kay, & Curtiss, 1993)	This test measures cognitive flexibility and problem-solving modification upon receiving feedback after each trial.
2	Wason Rule Discovery Test (Wason, 1960)	Participants are required to guess the underlying rule of a provided sequence of 3 numbers (e.g., 369). They are then asked to describe the rule followed by feedback.
3	Verbal Fluency Test (Spreen & Benton, 1969; Spreen & Risser, 2003)	This test measures semantic response generation speed. Participants are provided specific letters of the alphabets and are asked to generate common words for a minute.
4	Unravel Task (Altman et al., 2014)	This task requires participants to perform seven complex tasks in a prescribed order (UNREVAL) without repeating or skipping the steps. Distractor tasks are also introduced which require participants to enter the exact key for them to return back to their place in the trial sequence.
5	*Design Fluency Test (D-KEFS; Delis et al., 2001a, b)	This task measures non-verbal problem-solving approach, by asking participants to rapidly generate novel visual patterns within a structured task.
6	Tower of London (Shallice, 1982)	Participants are asked to arrange 3 colored discs in three provided pegs using fewest possible moves. These tasks measure planning, cognitive flexibility and problem-solving
7	Stroop Test (Stroop, 1935)	The task measures the interference of color word reading on the color naming. Participants are asked to name the color of the ink while inhibiting reading the word

D-KEFS battery consists of several subtests that measures various facets of executive functioning and mental flexibility.

APPENDIX C

EF AND BRAIN REGIONS

EF Ability	Brain Region
Attention	Top-down processes: dorsal attention network (DAN) comprising intraparietal sulcus (IPS), frontal eye fields (FEF); Bottom-up processes: ventral attention network (VAN) comprising right temporo-parietal junction (TPJ) and ventrolateral prefrontal cortex (vlPFC).
Inhibition	Right vlPFC, anterior insula (AI), inferior frontal junction (IFJ), vlPFC, anterior cingulate cortex (ACC), dlPFC, superior parietal lobe
Working Memory	Executive control network (ECN) comprising dorsolateral PFC, vlPFC, premotor, and parietal cortices.
Cognitive Flexibility	Premotor cortex, inferior and superior parietal cortices, inferior temporal cortex, occipital cortex, and subcortical structures such as the caudate and thalamus, vlPFC, dlPFC, anterior cingulate, right AI,

APPENDIX D

TOM AND BRAIN REGIONS

ToM Domains	Brain Regions
*[1] Perception of social stimuli	Extra-striate body area (EBA) for perception of body parts, fusiform face area (FFA) perception of faces
*[1] Gauging emotion and motivation	Amygdala (AMY), Anterior insula (AI), subgenual and perigenual anterior cingulate cortex (ACC), along with orbitofrontal cortex (OFC), supported by the subcortical structures of ventral striatum (VS), and hypothalamus (HTH).
*[1] Behavioral Adaptation	Dorsolateral, medial prefrontal cortex (dlPFC, mPFC), ACC. maintained with the support of the above-mentioned regions.
*[1] Social cognitive attribution	mPFC and temporo-parietal junction (TPJ) along with ventral premotor cortex (vPMC), superior temporal sulcus (STS), AI, posterior cingulate cortex (PCC), and precuneus (PC)
Domain-Specific ToM	TPJ, inferior parietal lobe at the junction of the posterior temporal cortex, medial prefrontal cortex, anterior paracingulate cortex, precuneus/posterior cingulate cortex, and superior temporal sulcus/medial temporal gyrus
Domain-General ToM	Anterior insula, IPL, temporoparietal junction (TPJ), vmPFC, dmPFC, IFG, dMPFC and insula region STG, MTG supramarginal gyrus, and precuneus.

APPENDIX E

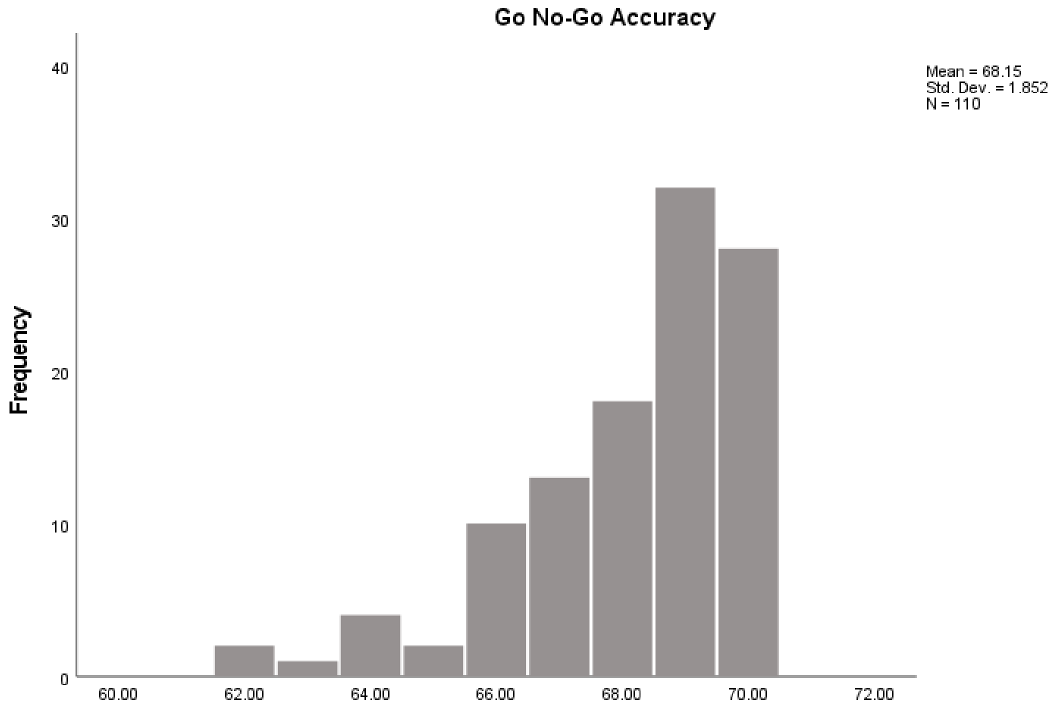
EF AND TOM SHARED BRAIN REGIONS

Brain Region	ToM function	EF Ability
Anterior insula	Understanding emotional states, *[1]motivation and emotion appraisal	Supports cognitive flexibility, coordination between top-down and bottom-up attention (*[2]mid-insula)
PFC	Self-perspective (dmPFC and mPFC)	Inhibitory control, working memory
vlPFC	Self-other perspective comparison	Selective attention and inhibition, cognitive flexibility.
dlPFC	*[1] Goal directed behavior, adaptive behavior	*[2] Cognitive flexibility, working memory
TPJ	Other-belief recognition	Implemented in attention, a "circuit breaker" for inhibiting, switching, and redirecting attention, working memory
Inferior Frontal Gyrus (IFG)	Self-perspective inhibition	Inhibition and response update, working memory
Anterior Cingulate Cortex (ACC)	Belief and desire reasoning	*[2] Response selection (dACC), Attentional control
Superior Temporal Sulcus (STS)	Social schemas and attribution	*[3] Perception and attention (face, voice, language)

*[1] (Billeke & Aboitiz, 2013)
*[2] (Dajani & Uddin, 2015)
*[3] (Beauchamp, 2015)

APPENDIX F

FREQUENCY DISTRIBUTION AND PLOTS


Go No-Go Accuracy
Mean = 68.15
Std. Dev. = 1.852
N = 110
Frequency
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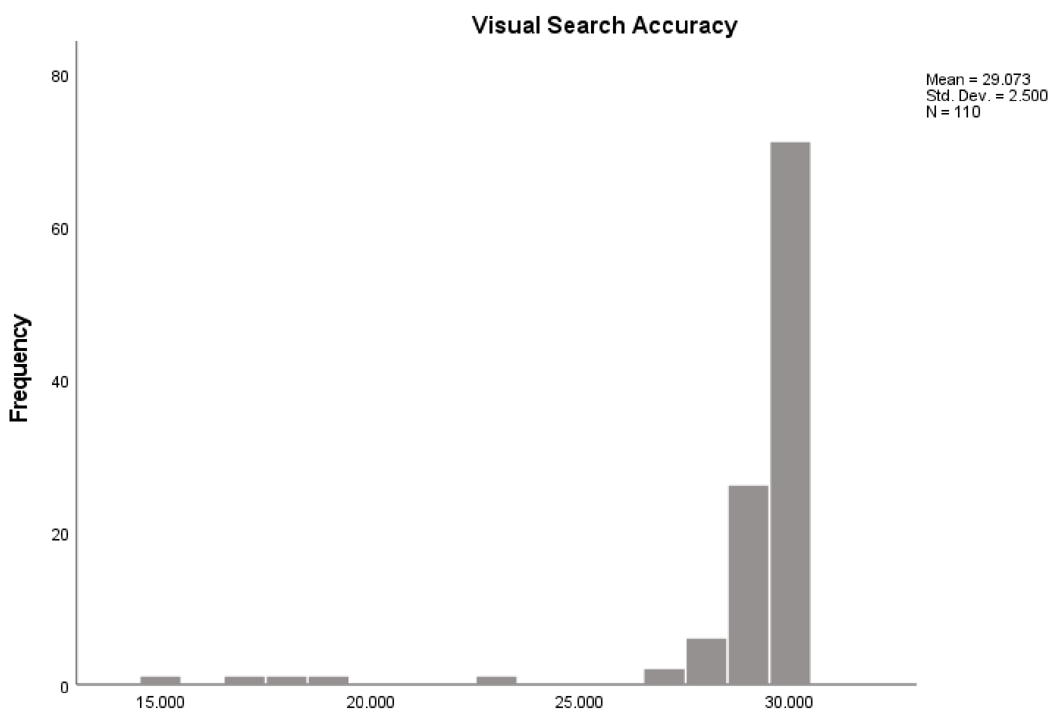
20
30
40
60.00
62.00
64.00
66.00
68.00
70.00
72.00


Visual Search Accuracy
Mean = 29.073
Std. Dev. = 2.500
N = 110
Frequency
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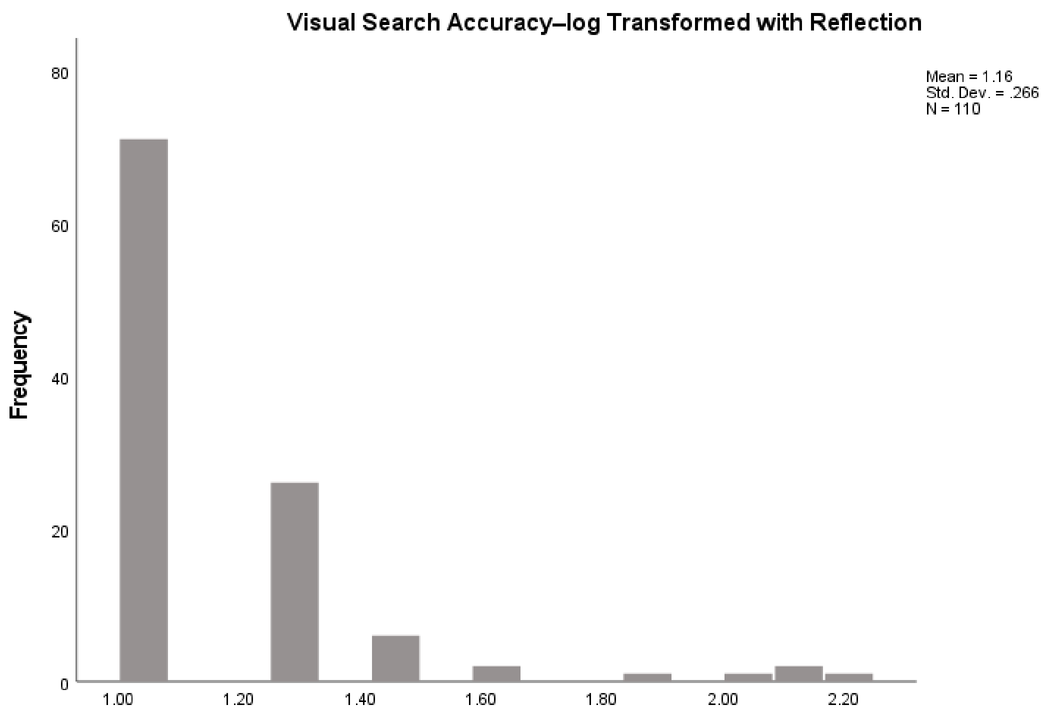
40
60
80
15.000
20.000
25.000
30.000


Visual Search Accuracy–log Transformed with Reflection
Mean = 1.16
Std. Dev. = .266
N = 110
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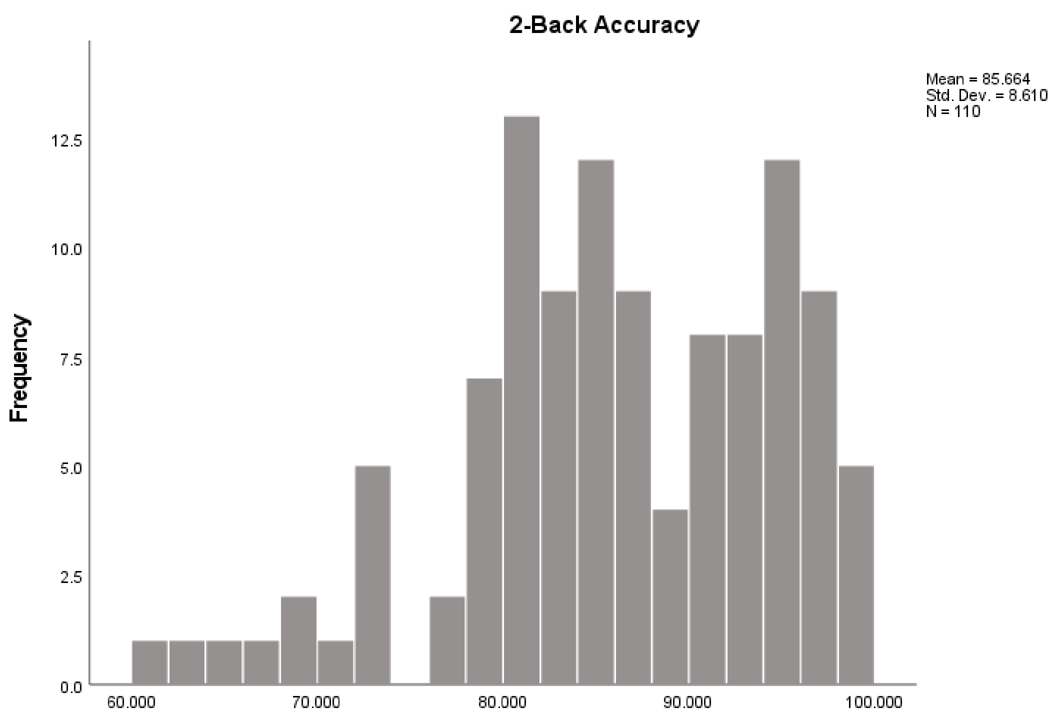
60
40
20
0
1.00
1.20
1.40
1.60
1.80
2.00
2.20


2-Back Accuracy
Mean = 85.664
Std. Dev. = 8.610
N = 110
Frequency
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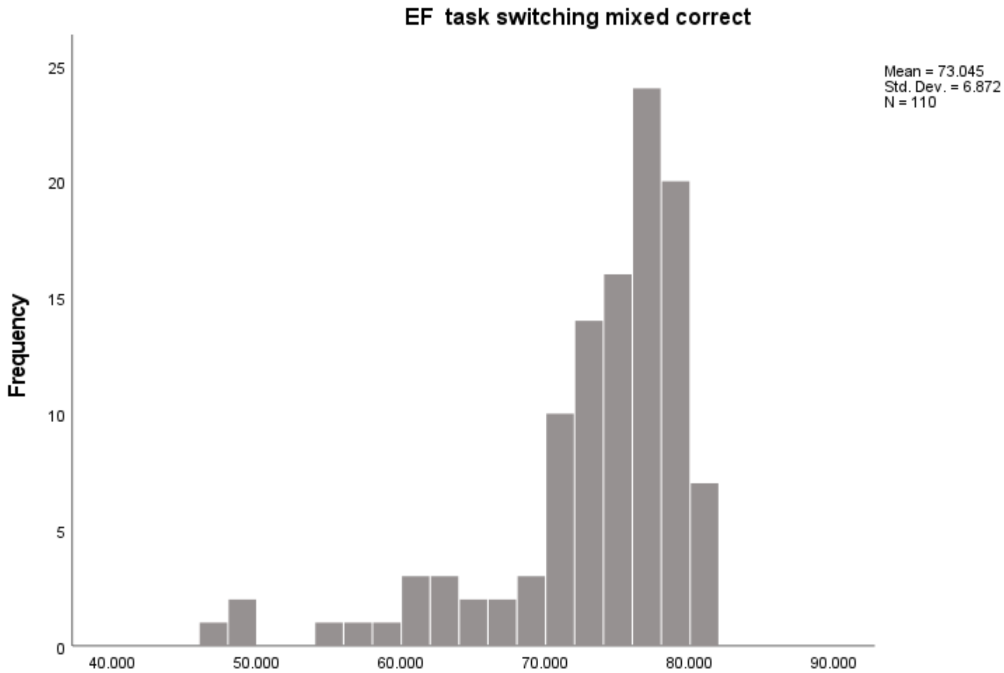
10.0
7.5
5.0
2.5
0.0
60.000
70.000
80.000
90.000
100.000


EF task switching mixed correct
Mean = 73.045
Std. Dev. = 6.872
N = 110
Frequency
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15
20
25
40.000
50.000
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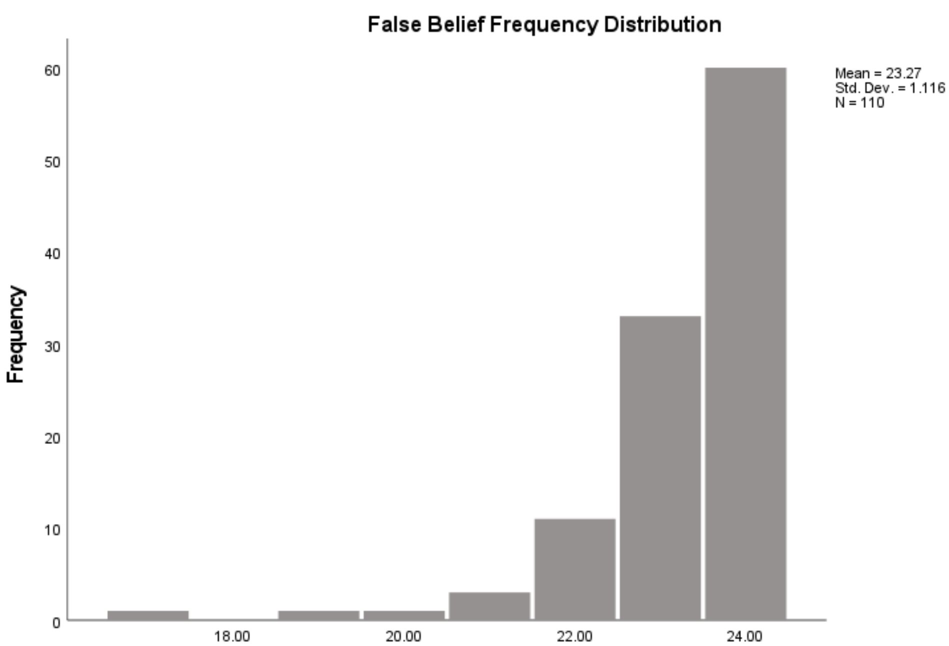
70.000
80.000
90.000


False Belief Frequency Distribution
Mean = 23.27
Std. Dev. = 1.116
N = 110
Frequency
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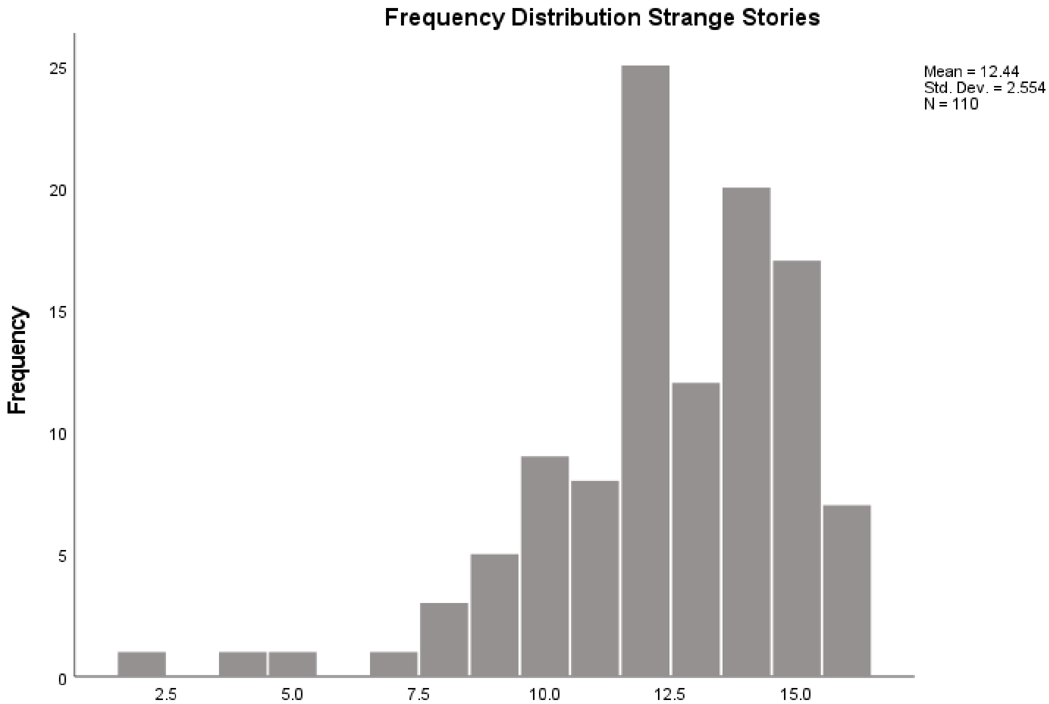
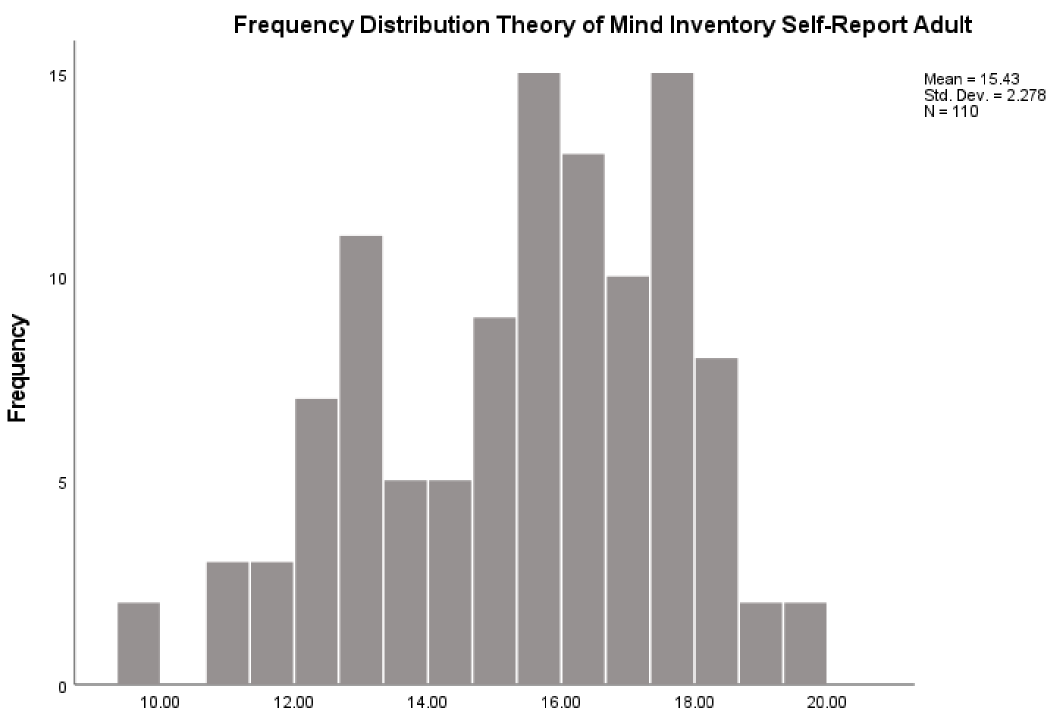
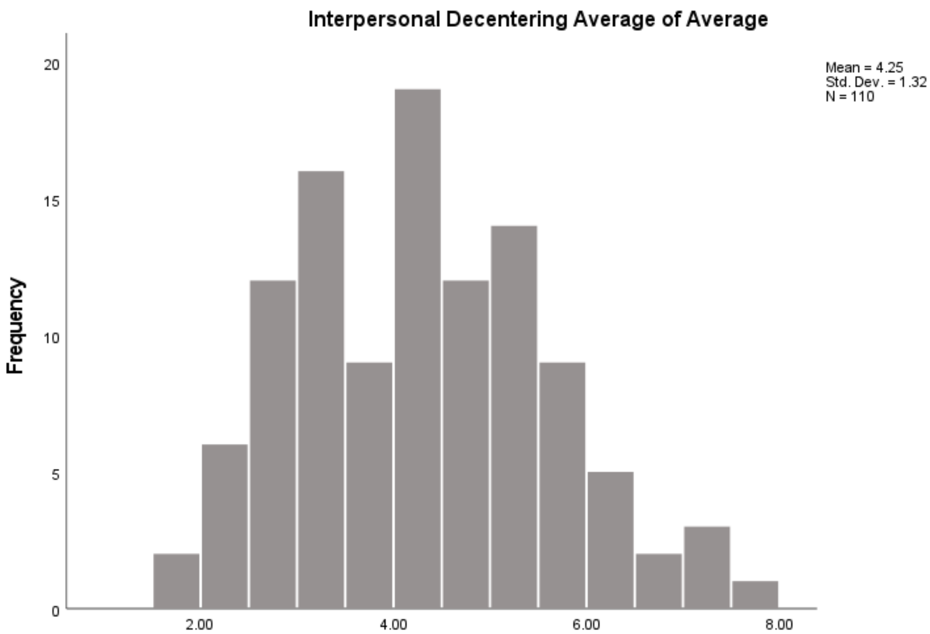
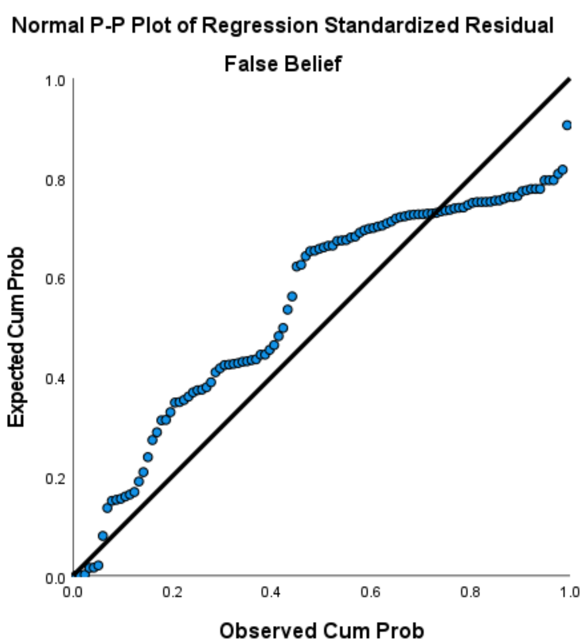
20
30
40
50
60
18.00
20.00
22.00
24.00

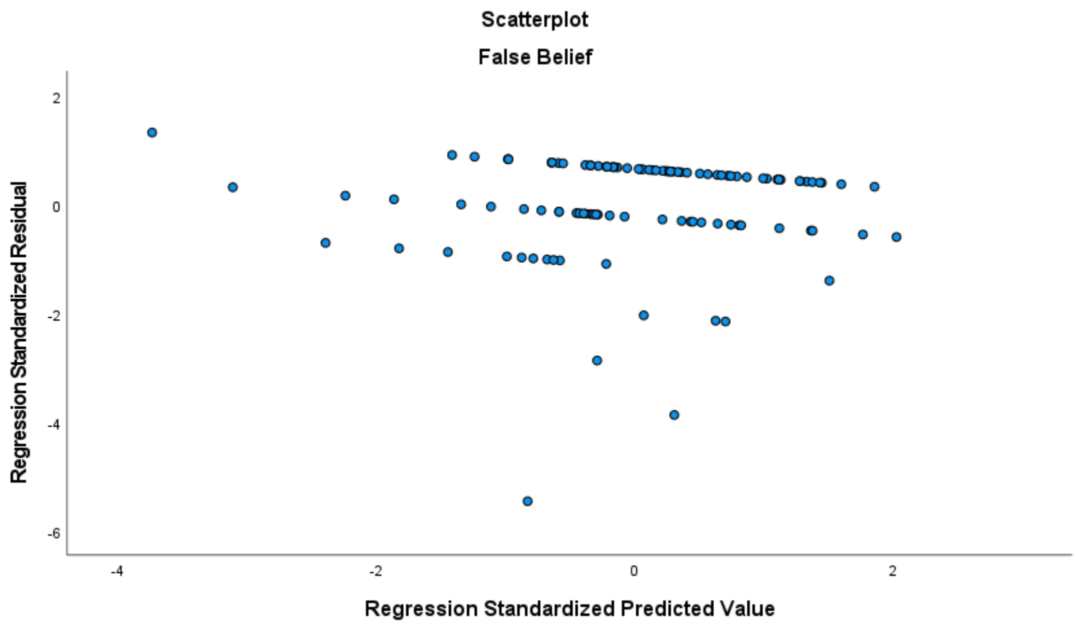

Frequency Distribution Strange Stories
Mean = 12.44
Std. Dev. = 2.554
N = 110
Frequency
0
5
10
15
20
25
2.5
5.0
7.5
10.0
12.5
15.0


Frequency Distribution Theory of Mind Inventory Self-Report Adult
Mean = 15.43
Std. Dev. = 2.278
N = 110
Frequency
0
5
10
15
10.00
12.00
14.00
16.00
18.00
20.00

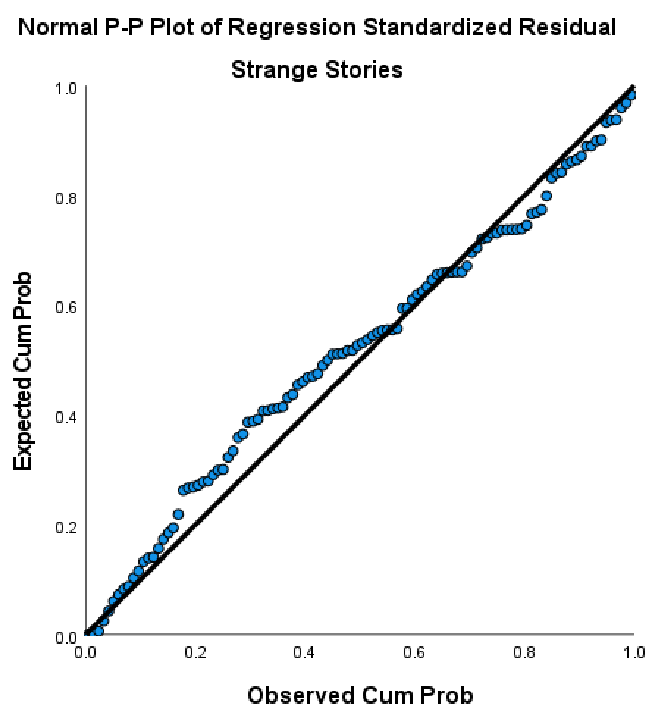


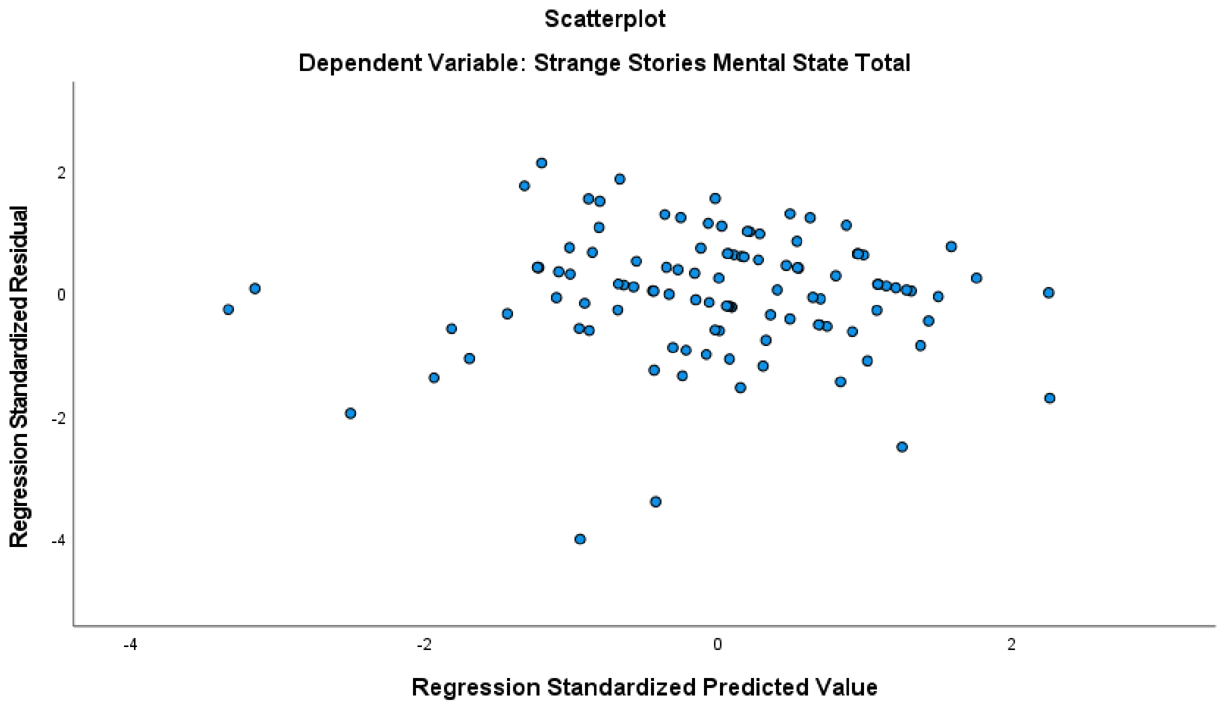
False Belief



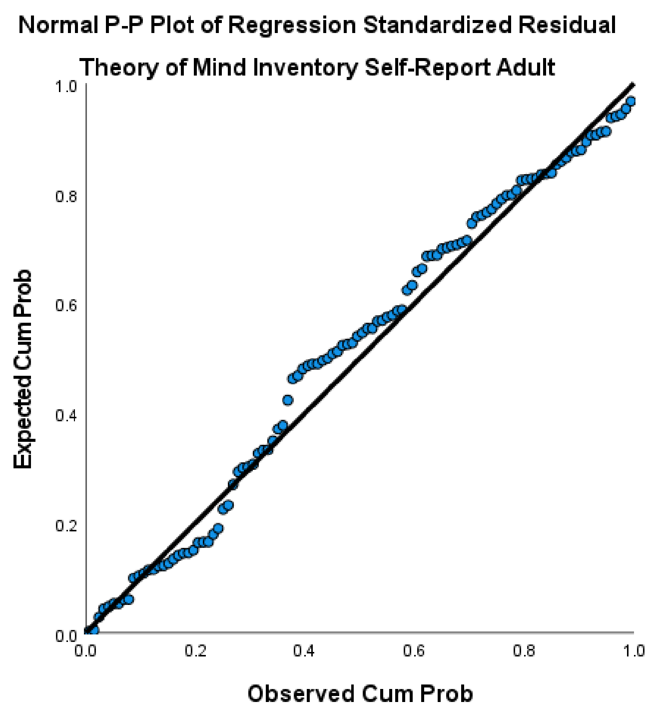


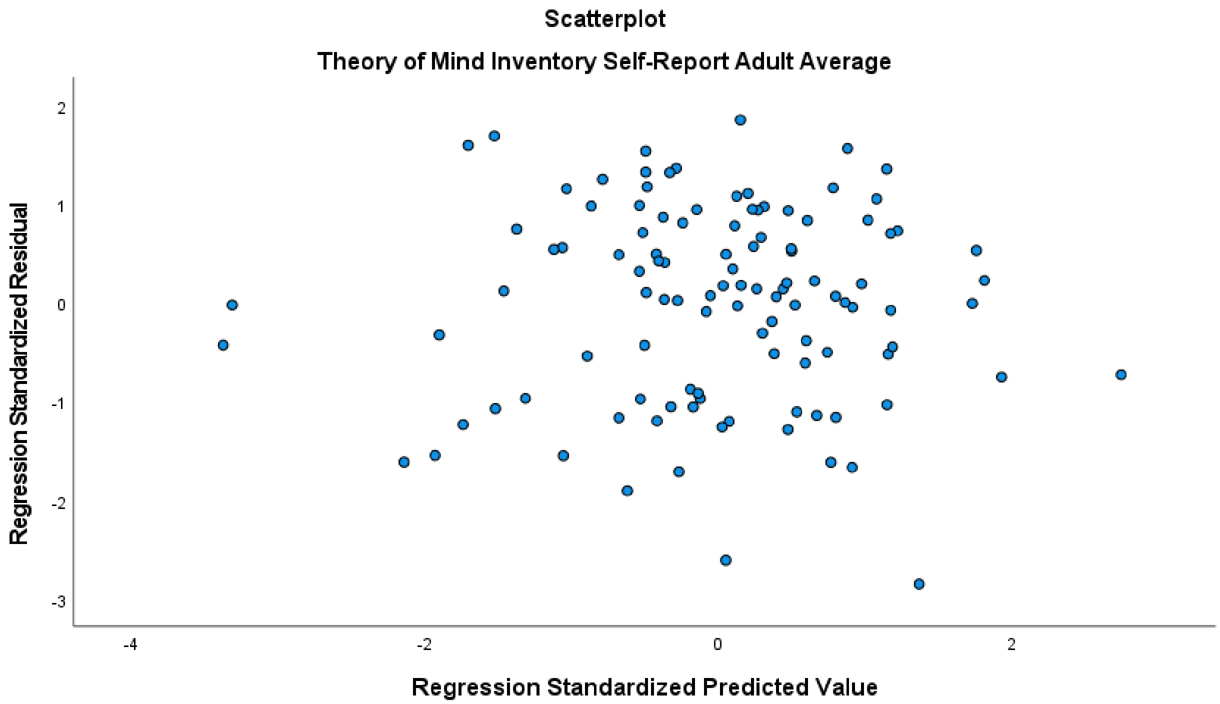
Strange Stories



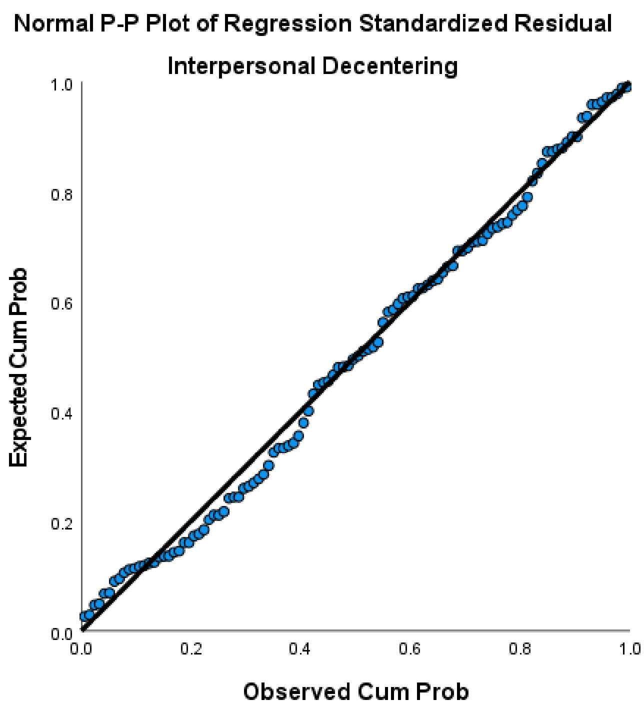

Scatterplot
Dependent Variable: Strange Stories Mental State Total
Regression Standardized Residual
Regression Standardized Predicted Value
2
0
-2
-4
-4
-2
0
2

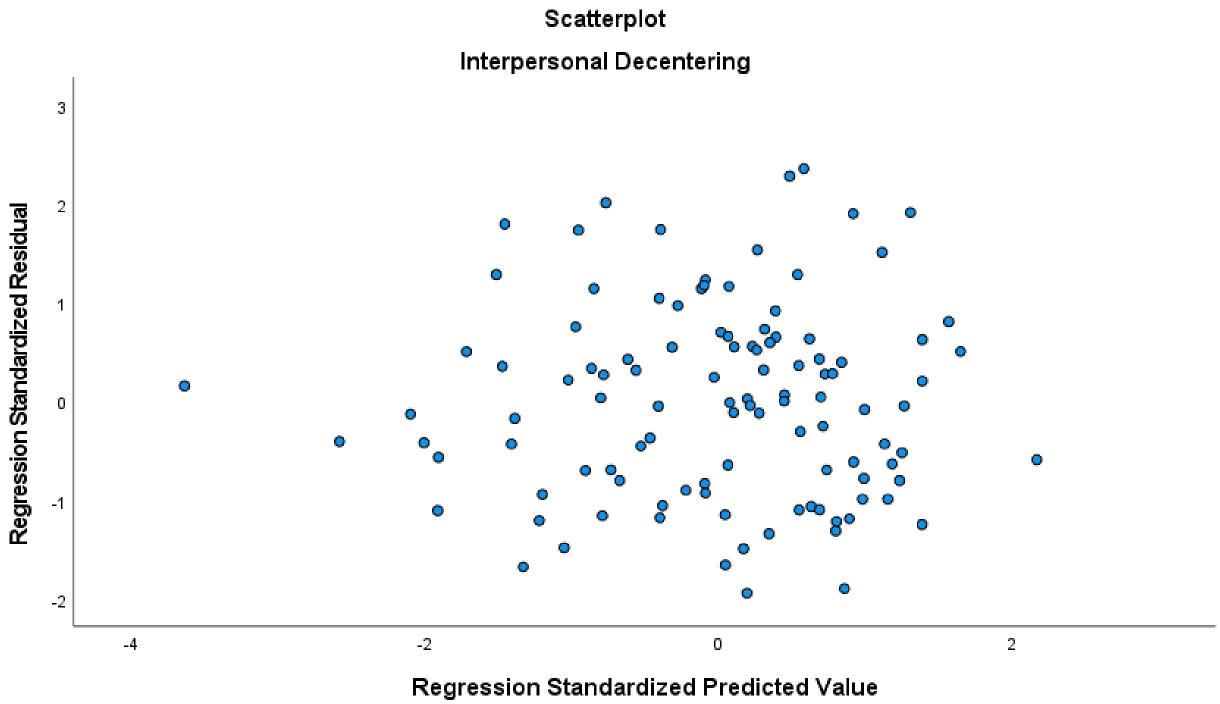
TOMI-SR-A


Normal P-P Plot of Regression Standardized Residual
Theory of Mind Inventory Self-Report Adult
Expected Cum Prob
Observed Cum Prob
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0



Interpersonal Decentering




Scatterplot
Interpersonal Decentering
Regression Standardized Residual
3
2
1
0
-1
-2
-4
-2
0
2
Regression Standardized Predicted Value

APPENDIX G

TAT INSTRUCTIONS FOR ONLINE ADMINISTRATION

You will see a series of pictures, and I would like you to make up stories about the people shown in the pictures. Tell whatever story comes to your mind about what is happening, who the people are, what they are feeling, thinking, and wanting. Tell what led to the situation shown, what they will do, and how everything will turn out in the end. Try to tell a whole story, with a beginning, middle, and end, about each picture.

Each picture will be shown for 20 seconds. After it has disappeared, please type your story in the window presented on the screen. Write whatever story comes to your mind. You will see some guiding questions to help you cover a story plot, but you do NOT need to answer them specifically. Any kind of story is all right; details of the picture don't matter.

Don't worry about grammar, spelling, or punctuation - they are not of concern here. You will have five minutes for each story; the computer will warn you when you have a minute left.

If you think that you have done something like this before, please just write whatever story comes to mind now.

Prompts to show above writing screen:

1. What is happening? Who are the people?
2. What has led up to this situation? That is, what has happened in the past?
3. What is being thought and felt? What is wanted? By whom?
4. What will happen? What will be done? How will it end?

Picture timed out after 5 minutes:

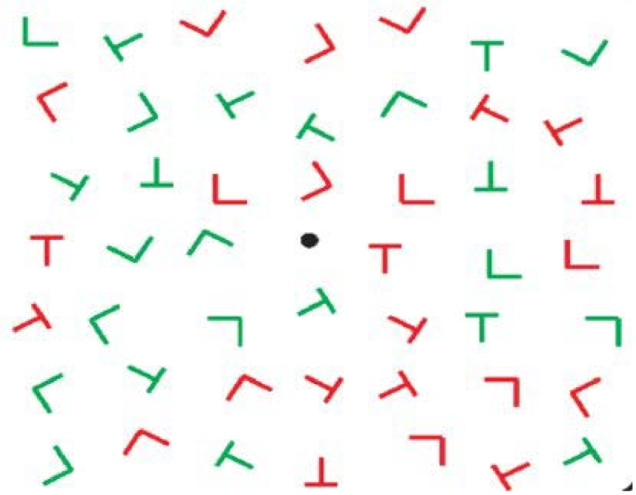
APPENDIX H

EF TASKS USED IN THE PRESENT STUDY

Attention

Visual Search Task (to measure attention): https://www.psytoolkit.org/experiment-library/search.html

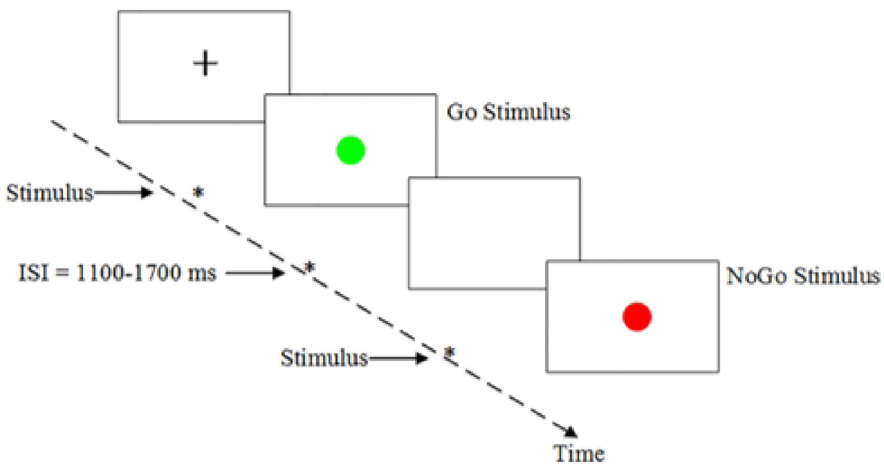
"In the following task, you are required to find an upright orange T amongst blue Ts and upside-down orange Ts. Again, all you need to do is find an orange T. If you see the orange T, press space. Ignore the upside-down orange T, as well as blue Ts. It is very important to respond as fast as you can. If there is no orange T, wait for the next trial and do nothing."



Inhibition

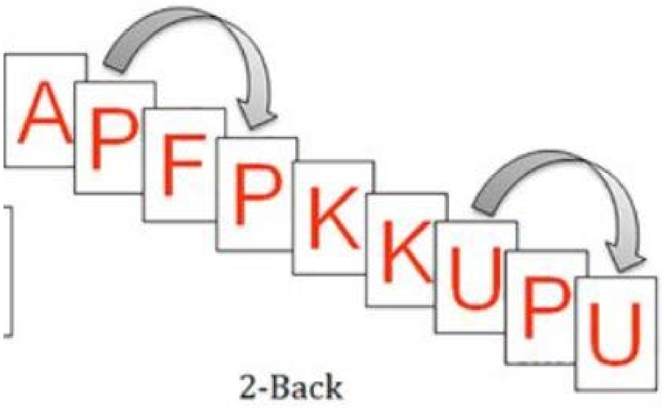
Go/No-go task (to measure inhibition): https://www.psytoolkit.org/experiment-library/go-no-go.html

"In the following trials, only press the space bar if you see the message "GO press the space bar" in green and do nothing if you see "NOGO press nothing" in red.



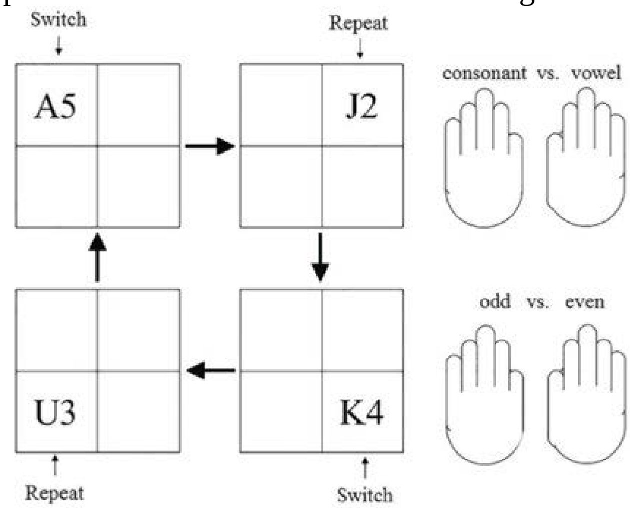
Working Memory

N-Back task / 2-Back task (to measure working memory):
https://www.psytoolkit.org/experiment-library/nback2.html
"In this task, you will see letters. Each letter is shown for a few seconds. You need to decide if you saw the same letter two letters ago. If you saw the same letter two letters ago, you press the "m" key. If you did it correctly, you will see the green color around the letter. If you press the button when you should not press it, you will see "red" around the letter."



Cognitive Flexibility

Task-switching paradigm (alternating runs version; to measure cognitive flexibility):
https://www.psytoolkit.org/experiment-library/taskswitching.html
In the following task, you respond with button presses to letters and numbers. You will only need two keys (B and N). You will always see a letter/number combination, for example, G1. If the letter/number combination appears at the top of the screen, you need to respond to the letter. If the letter/number combination appears at the bottom of the screen, you need to respond to the numbers. Moreover, if you see a consonant on the top of the screen, press B if you see vowels, press N." The screen will also show images of the expected task and examples.



APPENDIX I

DEMOGRAPHICS QUESTIONNAIRE

1. Age (Type-in)______

2. Which of the following best describes your race/ethnicity (please select all that apply):

    1. African American (Black)
    2. Asian/Asian-American
    3. European/White/Caucasian
    4. Latinx/Latino American/ Hispanic
    5. Middle Eastern
    6. Native American/First Nation
    7. Native Hawaiian/Pacific Islander
    8. Type-in:________________

3. Country of birth (type-in): ___________________________

4. Which of the following best describes your religious affiliation? (Check all that apply)

    1. Agnostic
    2. Atheist
    3. Buddhist
    4. Catholic
    5. Christian
    6. Hindu
    7. Jewish
    8. Mormon
    9. Muslim
    10. Protestant
    11. Religious unaffiliated
    12. Secular unaffiliated
    13. Don’t know

14. Type-in: ________________________________

5. If you are currently a student, which of the following best describes your current class rank

    1. Freshman
    2. Sophomore
    3. Junior
    4. Senior
    5. Graduate Student
    6. Type-in:________________

6. What is **your** current level of completed education?

    1. Some high school
    2. High school diploma or GED
    3. Less than 2 years of college
    4. 2-4 years of college
    5. 4-year college degree
    6. Master’s degree
    7. Doctorate degree
    8. Type-in:________________

7. What is **your mother’s** highest level of education completed?

    1. Some high school
    2. High school diploma or GED
    3. Less than 2 years of college
    4. 2-4 years of college
    5. 4-year college degree
    6. Master’s degree
    7. Doctorate degree

8. Type-in:________________

8. What is **your father's** highest level of education completed?

    9. Some high school

    10. High school diploma or GED

    11. Less than 2 years of college

    12. 2-4 years of college

    13. 4-year college degree

    14. Master's degree

    15. Doctorate degree

    16. Type-in:________________

9. How many brothers and sisters do you have

    1. 0

    2. 1

    3. 2

    4. 3

    5. 4

    6. 5 or more

10. What is your sex assigned at birth?

    1. Female

    2. Male

    3. Intersex

    4. Type-in:________________

11. Which of the following best described your gender identity? (Choose all that apply)

    1. Agender

    2. Androgynous

3. Cisgender man
4. Cisgender woman
5. Demigender
6. Genderqueer or gender fluid
7. Non-binary
8. Questioning or unsure
9. Trans man
10. Trans woman
11. Two-spirit
12. Type-in:_______________

12. Which of the following best describes your sexual orientation? (Choose all that apply)

    1. Asexual
    2. Bisexual
    3. Demisexual
    4. Gay
    5. Lesbian
    6. Pansexual
    7. Queer
    8. Questioning or unsure
    9. Same-gender loving
    10. Type-in:_______________

13. How would you describe your relationship status?

    1. Married
    2. Divorced
    3. Widowed

4. In a committed relationship
5. Dating someone steadily
6. Single
7. Type-in:_______________

14. Do you have children?

- No
- Yes
- If yes, how many children (type-in)? _____

15. Which of the following best describes the social-economic status of your family of origin?

1. Lower class
2. Upper lower class
3. Lower middle class
4. Upper middle class
5. Upper class

16. Which of the following categories best describes your employment status?

1. Employed, working 1-20 hours per week
2. Employed, working 21-39 hours per week
3. Employed, working 40 or more hours per week
4. Not employed, looking for work
5. Not employed, NOT looking for work
6. Disabled, not able to work
7. Retired
8. Type-in:_______________

17. Are you fluent in English?

1. Yes, English is my first language

2. Yes, I am natively bilingual; I also grew up speaking (type-in): ____________

3. No

   a. If no, what is your native language? (type-in): ____________

   b. If no, your English proficiency is

      1. Elementary proficiency

      2. Limited working proficiency

      3. Professional working proficiency

      4. Full professional proficiency

Leisure Activities

18. Do you enjoy reading novels, short stories, or biographies? __Yes __No

- IF YES: gate to
- Do you typically imagine yourself as one of the characters? __Yes __Sometimes __No
- Do you ever visualize the setting or action as you read? __Yes __Sometimes __No
- Do you have a favorite genre (e.g., mysteries, science fiction, romance, etc.)?
- __No __Yes --> Please describe____________

19. Do you currently play, or have you ever played Tabletop Role Playing Games (TTRPGs), like Dungeons & Dragons for example? 0) Never played 1) Yes, used to play 2) Yes, currently play

IF EITHER YES: gate to the following:

1) How long have you played/did you play?

   a. Less than 1 year

   b. 1-2 years

   c. 2-5 years

   d. 5-10 years

   e. 10+ years

2) About how often in the past year have you played?

   a. Never

   b. Less than once a month

   c. One to three times a month

   d. Once a week

   e. Several times a week

   f. Daily

3) How long are your typical play sessions?

   a. 0) Less than 1 hour

   b. 2) 1 hour

   c. 3) 2 hours

   d. 4) 3 hours

   e. 5) 4 hours

   f. 6) 5-6 hours

   g. 7) 7-10 hours

   h. 8) 11 or more hours

4) Do you prefer to run or play the game? 0) Run 1) Play 2) Both equally

5) How often do you <u>consider your characters thoughts, feeling, or personality</u> when playing Dungeons and Dragons or any other tabletop RPG?

   a. Never

   b. Rarely

   c. Sometimes

   d. Often

   e. All the time

6) Do you engage in "Meta-gaming"* when playing Dungeons and Dragons or any other tabletop RPG?

a. Never/ Don’t know what that is

b. Rarely

c. Sometimes

d. Often

e. All the time

- *Meta-gaming is when someone uses information that the character they are playing in game wouldn’t know. For example, an experienced player might know a monster’s weakness but would “role play” as if his character did not because his characters has never seen this type of monster.

20. Your handedness

    1. Left-Handed
    2. Right-Handed
    3. Ambidextrous (Equally proficient using both hands to complete tasks (e.g., writing)

21. Do you wear prescription glasses?

    1. No
    2. Yes

22. Have you had a diagnosis of epilepsy or have been treated for seizures?

    1. Yes
    2. No

23. Have you ever been diagnosed with an Autism spectrum disorder or Asperger’s Syndrome?

    1. Yes
    2. I have wondered whether I have it, but have not been diagnosed

    [If wondered] What have you noticed that made you wonder? (type-in)________________

    3. No

24. Have you ever been diagnosed with Attention Deficit Hyperactive Disorder or Attention Deficit Disorder?

    1. Yes

2. I have wondered whether I have it, but have not been diagnosed

[If wondered] What have you noticed that made you wonder? (type-in)_______________

3. No

25. Have you ever been diagnosed with a major mental health disorder? (Examples: Major Depression, Anxiety, Bipolar Disorder, Psychotic Disorder)

    1. Yes

    2. No

26. Do you have a history of problems with your memory?

    1. Yes Please describe? (type-in)____________

    2. No

27. Do you currently use medicines for anxiety, depression, ADHD etc., or recreational drugs (Including alcohol, cigarettes, or vaping) This information will be kept confidential.

    1. Yes

    2. No

28. Please list the drugs or medicines you are currently using. Your responses will be kept confidential and anonymous.

    Type-in ___________

29. Have you ever had a serious head-injury in which you blacked out and/or required hospitalization?

    1. No

    2. Yes

        a. If yes, how long did you black out:

            1.30 minutes or less

            2.More than 30 minutes

        b. If hospitalized for head injury

            1.one day or less

2.more than a day

30. Have you ever had brain surgery?

1. Yes
2. No

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